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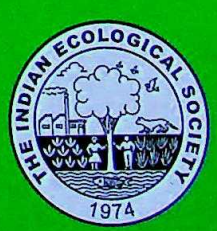
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Urbanization and its Impact on Groundwater and Natural Drainage: A Case Study of Ludhiana City

Karamjit Singh, Deepti Singh and Ajay Mathur

Punjab Remote Sensing Centre, PAU Campus, Ludhiana-141001, Punjab, India
E-mail: kjeet12@gmail.com

Abstract: Urbanization is generally increasing worldwide as well as land is in a constant flux of continual changes due to the transformation resulting from either natural processes or human activities. Remote Sensing and GIS techniques are widely used for the mapping of land use/land cover to examine the changes in urbanization. Its impact on groundwater physio-chemical characteristics and natural drainage has been examined in this study. Cartosat-I and IRS-P6 (LISS-III) satellite data along with toposheets of the year 1960 were used to study temporal changes for a time span of forty six (1960-2006) years for a localized area in Ludhiana city. Analysis of multidate data spanning over this period shows that total area under built up category of the city had increased by 39 % and 42 Km long paleochannel has been obliterated. Results of this study illustrate that urbanization had widely affected the groundwater quality and course of natural drainage due to which various problems like flooding and deterioration of groundwater quality has occurred.

Key Words: GIS, Groundwater, Natural drainage, Remote Sensing, and Urbanization

Land is generally in a constant flux of continual changes due to the transformation resulting from either natural processes or human activities. Since the beginning of the civilization, large scale land transformation is being witnessed in and around major cities of the world. The changes have been very rapid, haphazard and dynamic especially in the urban fringe due to growing population. The main factors affecting the urban fringe land transformation are growth of industrial, commercial and residential activities. Urbanization is a process through the loss of productive agricultural lands, forests, surface water bodies and groundwater. (Pathan *et al.,* 1989 & 1993).

Urbanization is increasing worldwide. In 1900, only 10% of the world's population lived in cities; for the year 2000 their number is estimated at 50% (UN 1991). The ten biggest cities on Earth, the so-called mega-cities, have an average population of 7.03 check. (United States Census Bureau, 2011). The population growth rate of world is 1.167% The Projected population of the World by 2050 is 10.5 billion. (International Data Base (DB)-World Population-Census.gov. 2010-06-28. Retrieved 2010-08-01).The urban population of the world is 50.55 % of the total population with a 1.85% annual rate of change. (Central Intelligence Agency, The world Factbook, 2010). The broad land use of world can be classified in terms arable land, permanent crops, irrigated land and others (Fig.1).

India is second most populated country in world after China, and also categorized as growing country, having a total population of 1,353,050,000 and population density of 371 pop per Km^2. Its total share to the World Population is 17%. (Census of India, 2011, Retrieved 2012-05-22)

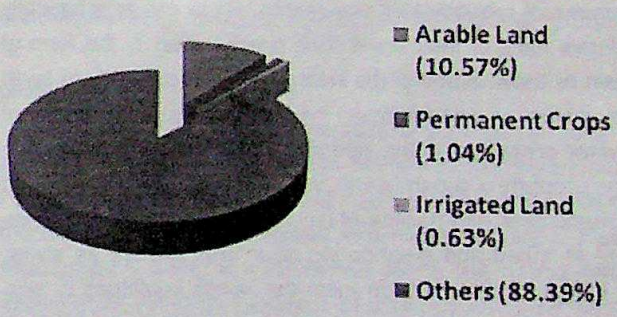


Fig. 1. Land use classification of World (*World fact book)*

(International Data Base (DB)-World Population-Census.gov. 2010-06-28. Retrieved 2010-08-01).

The population of India has more than doubled during the last four decades. Due to unplanned urbanization some of the best productive and agricultural land has been lost. In India, the percentage of population living in cities and urban areas was 28.6% in 2001, which has increased to 37.7% in 2011 with a 10% increase in last 10 years (Registrar general & census commissioner, India, Ministry of home affairs New Delhi: 15th July 2011).

With the global increase in population and infrastructure, nations like India have experienced a major land use change in every field, whether it may be in agriculture or urbanisation.The land man ratio is declining day by day. To sustain this rapid urban growth, development should be planned in a sustainable manner to fulfill all the facilities like infrastructure, drainage, water supply, sanitation, etc. To ensure sustainability, urban areas have to be properly monitored to maintain an internal equilibrium (Barredo and Demicheli *et al.*, 2003)

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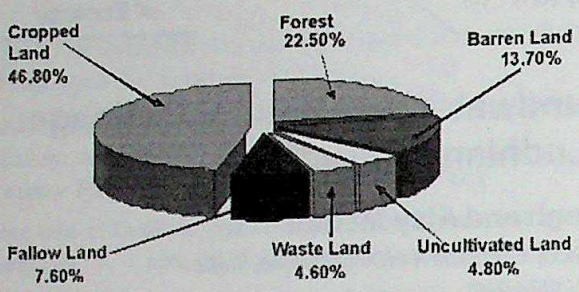


Fig. 2. Land use classification of India, 1996-1997

Forest cover is declining and agricultural area is increasing with the passage of time (Fig. 2).

Hydrological Features and their Significance

Rivers and drains are the most prominent fluvial features on Earth on which all the hydrological regimes of an area depend. Fluvial features like meander scars, palaeo/ abandoned channels and oxbow lakes are very good source of groundwater occurrence. River streams typically derive most of their water from precipitation in the form of rain or snow. Some of the water proceeds to sink into earth by infiltration and becomes groundwater and the quality of water contained in the stream or drain cast its impact on the property of groundwater. With the passage of time, rapid urbanization and decline of land man ratio, these drainages are shrinked and meandering structures are left as scars. If erosion on the outside meander bends continues to take place, eventually a meander bend can become cut off from the rest of the stream. When this occurs, the cutoff meander bends, because it is still a depression, will collect water and forms a type of lake called an oxbow lake. These types of fluvial features are more prominent near the rivers and their quantity depends on the size of the river.

Status of Urban Sprawl in Punjab

The State of Punjab, where land man ratio is declining at a rapid pace due to high population growth is also facing steady decline and detoriation in its natural resources. The State has an area of 50,362 sq km with population of 2.77 crore (Census of India 2011).The population density is 482/ Km^2. Agriculture is the largest occupation in Punjab. Punjab is called the "Granary of India" or "India's bread-basket." Its overall cereals share to the national pool is 20.35% of wheat, and 18% of rice. (Source: PHD Research Bureau, compiled from RBI, Ministry of Agriculture).

Use of Remote Sensing and GIS for Land use/ Land Cover and Drainage Mapping

Remote sensing techniques can be widely used for the mapping of urban sprawl and monitoring the changes in land use/land cover (Pathan *et al.*, 2004; Donnay *et al.*, 2001). It has evolved as a powerful tool for monitoring rapid changes in the landscape and land use resulting from urban developments (Albert *et al.*, 2004).

The present study has been carried out to know the overall impact of urbanization on natural drainage and groundwater near Ludhiana city using remote sensing and GIS techniques. It is aimed to bring out the temporal change of urban land use/land cover and its impact on natural drainage of Ludhiana city and its periphery in Punjab using remote sensing technique in conjunction with Geographical Information System (GIS). The key objectives of this study were to analyze the temporal changes brought in urbanization during last forty six years and their impact on natural drainage and to assess the physio-chemical characteristics of groundwater by collecting georeferenced water samples.

MATERIAL AND METHODS

Location and Extent

Ludhiana city is one of the centrally located cities falling in the Malwa region of the state of Punjab. It is bounded on the north by the Sutlej River, which separates it from Jalandhar and Nawanshahar districts. The city is thickly populated having a total population of 1,613,878. (Census of India 2011). It's the main industrial hub of Punjab.

The study area comprises a small portion in flood plain of Ludhiana located near meharban village which is 6.5 Km towards NE direction from Ludhiana Railway station bounded by latitudes 30°56'10"N and 30°57'32"N and longitudes 75°53'10"E and 75°55'04"E.

The region falls in the Survey of India (SOI) map sheet numbers 44 N/13 and 44 M/16 (Fig. 4.)

Geomorphology Topography and Demography:

Geomorphologically, the area can be broadly divided into two major geographic units i.e. flood plain and alluvial plain. The flood plain is the area lying south of river Sutlej and varies from 5 to 25 Km in width. The alluvial plain is flat and is nearly level to very gently sloping. It owes its origin to the aggravation work of river Sutlej. The alluvium deposited by the river has been worked over by the wind, which gave rise to a number of small dunes and sand moulds. Most of the dunes have been leveled by the farmers.

Ludhiana city is an important industrial, trading, transport, economic and administrative base of Punjab state. Due to its central location within the heart of Punjab state and easy accessibility of trade and business, the city has grown very fast during the last few decades. The district which was having a total population of 2,428,400 as per Census 1991 had showed a fast increase in the last two

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decades and shot upto 3,487,882 in 2011.(Census of India, 2011, Retrieved 2012-05-22).The population of the city was mere 4, 01,176 in 1971 which had increased to 13, 95,053 in 2001. Ludhiana city is the second most populated city of the state after Amritsar with a current population of 1,613,878 which is 46.27% of the total population of the district. The graphical representation of population of the city since 1901 upto 2011 is shown in (Fig.4). (Source, Statistical abstract of Punjab).

In Ludhiana, lands are very productive and mainly cover crops, some part by plantation and remain as fallow. The major crops in the area are wheat and rice but some areas in the southern part of the district also have cotton and jute. Water table is also good, some areas near the river have groundwater occurrence at a depth of 30 to 40 feet and the alluvial plain areas at a depth of 80 to 100 feet.

Regarding plantations, poplar and eucalyptus are the common plants. There are also two reserve forests namely Ludhiana reserve forest and Mattiwara reserve forest in the district.

Georeferenced Cartosat-I* data of the year 2006 with a spatial resolution of 2.5m and IRS-P6 (LISS-III) of 2006 with spatial resolution of 23.5 m satellite data was used to interpret the land use/land cover of the study area. False color composite (FCC) was generated with LISS-III data for geomorphological mapping of the study area.

Survey of India (SOI) map sheets on the scale of year have been used to prepare the base map of the study area. Aerial photographs of the year 1960 have also been taken for visual interpretation through standard visual interpretation keys such as shape, tone, texture and pattern. (**Polyconic, GCS Indian 1954*)

Oxbow lake

Scanned toposheets were registered with respect to the Cartosat-I image and vector layer was generated for Land use/Land cover required features (Roads, Railway tracks, Settlements, Water bodies and Forests). These area captured through on-screen digitization in Arc GIS software, of the study area for the year 1960. Similar procedure was done for Cartosat-I image. Thematic maps of land use/land cover of the study area were prepared for the years 1960 and 2006.The boundary separating the flood plain and alluvial plain and city boundary were demarcated using LISS-III.

Ground truth

The field tour programme was organized on 16-11-2007. During this, an oxbow-lake, delineated using Cartosat-I data, was selected for detailed investigations. The width of the oxbow-lake was measured with measuring tape. Field photographs were also collected along the oxbow-lake showing urbanization, blockage of drainage and poor water quality. (Fig. 5).

Collection of Water Samples

Thirteen water samples were collected along the Oxbow lake from tube wells and hand pumps (shallow aquifers) with GPS locations to check the drinking quality of water by undertaking chemical analysis. The depth of the samples

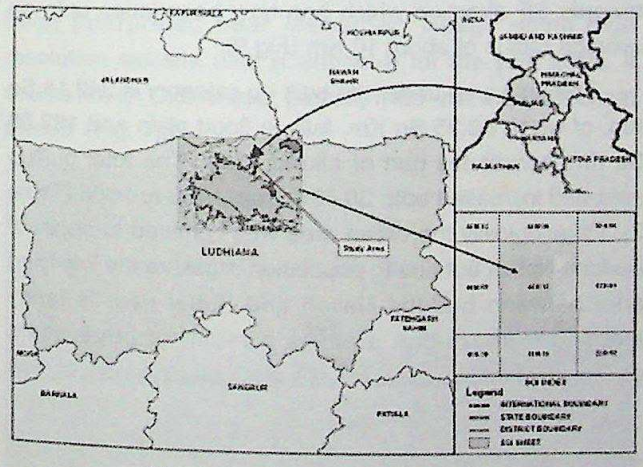


Fig. 3. Location map of study area

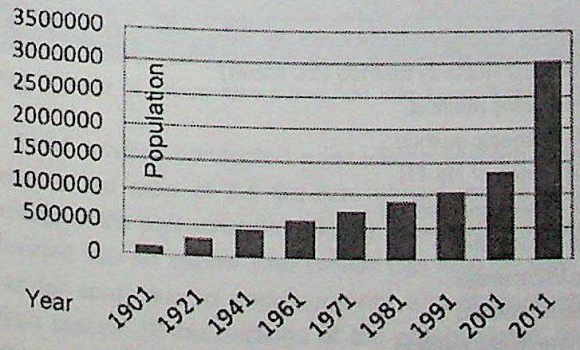


Fig. 4. Population graph of Ludhiana



Fig.5. Urbanization showing blockage of drainage

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collected varies from 75 feet to 400 feet.

The water samples were collected directly from the tube wells and hand pumps after continuous pumping for 10-15 minutes. Good quality, air tight plastic bottles with cover lock were used for sample collection and safe transfer to th e laboratory for analysis.

Samples were taken after thoroughly rinsing the bottle with water to be sampled. Water sampling was carried out following the standard procedures (APHA, 1992). During survey, comments from the residents of the study area were taken which helped in the overall discussion on the matter. Georeferenced water sample (GPS) locations were used to form a map. (Fig. 6).

Chemical analysis of water samples

The samples were analyzed for 10 physico-chemical parameters namely pH, EC, Na^+, K, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, NO_3^- and TH (total hardness) using following methods (Table 2).

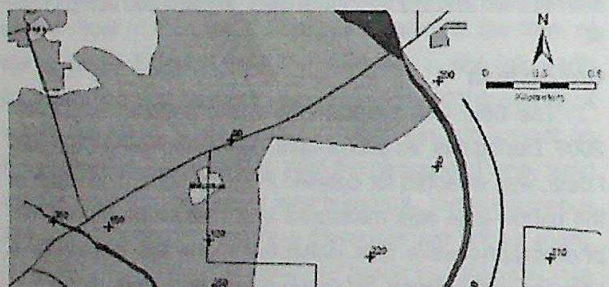


Fig.6. Map showing water samples with ground depth (in feet) collected from the field

RESULTS AND DISCUSSION

Land use/Land cover changes over last forty six years

Analysis of multidate data spanning over forty six years (1960-2006) period shows that there has been a rapid development in and around Ludhiana city. The total area under built up category having an expanse of 22.04 Sq Km in 1960 out of which the Ludhiana city had a spread of only 18.5 Sq Km, and city was well within the alluvial plain (A.P) and not in the danger zone of flooding. The flood plain (F.P) comprises of 303 Sq Km whereas the alluvial plain has a spread of 268.74 Sq Km. Sutlej River flows from east to west at the northern periphery of the region. There were 60 villages, with an area of 1.75 Sq Km in the flood plain zone, whereas 30 villages were in the alluvial plain along with city having an area of 20.29 Sq Km. (Table 3).

The most prominent hydrological features flowing through the study area were River Sutlej, Buddha Nallah and a 42 Km. long paleochannel during 1960. Out of these River Sutlej had a vast expansion, having a width of 6 Km at certain areas and a total area of 74 Sq Km. Seven channel bars having total area of 24.77 Sq Km were also visible (Fig 8).

Comparison of the maps for the year 1960 and 2006 shows that the expansion of the city has been seen more towards SE direction which has now boundaries upto an average radius of about 10 Km (Fig 9).

The total area under the built-up category is 242.15 Sq Km. of which 58.35 Sq Km. falls in flood plain and 183.80 Sq Km. constitutes part of alluvial plain. The total builtup area had increased upto 38.43% from 1960 to 2006 (Table 3). Paleologically the urban area was confined to south of Buddha Nallah but due to population pressure the low lying area between Buddha Nallah and Sutlej river is fastly merging in the urban area as a result of large scale construction for industrial houses and establishment of new

Table 2. Physico-chemical analysis parameters

S.No.	Parameter	Method
1	pH	Electro-metric method (pH meter)
2	Electrical Conductivity (EC) µS/cm	Electrical conductivity method (EC meter)
3	Chloride (Cl^-) mg/l	Argentometric method
4	Calcium (Ca^{2+}) mg/l	EDTA-Titrimetric method
5	Magnesium (Mg^{2+}) mg/l	By Difference of Na TH
6	Bicarbonate(HCO^-_3) mg/l	H_2SO_4- Titrimetric method
7	Potassium(K)	Flame Photometer
8	Sodium(Na^+)	Flame Photometer
9	Nitrate(NO_3^-) mg/l	Titrimetric method
10	Total Hardness (TH) mg/l	EDTA-Titrimetric method

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housing colonies, educational institutions etc. Many of the villages surrounding the city are now the part of the Ludhiana Municipal Corporation.

Thirty three villages having an area of 1.877 Sq Km. along with agricultural area of 165.13 Sq Km. have been merged in the city now. The River which was having an area of 74.0 Sq Km. in 1960 has shrinked to an area of 13.67 Sq Km. showing 19.85% decline as observed in the flood plain zone.

Agricultural land has also shown a major decline of 28.06% but more loss is observed in the alluvial plain which is 60.84%.The expansion of the city in every direction is at the cost of most productive and fertile agricultural land. An increase of impervious surface has cast a deep impact on groundwater natural recharge.

Land use / land cover map of 1960 (Fig. 8) prepared from toposheets of the year 1960 shows that a perennial tributary (paleochannel) of River Sutlej was flowing in the north of Ludhiana city having a length of 42 Km. Due to rapid growth of population and diversification of builtup areas, it has been, shrinked and blocked, leaving behind few meander scars.

One such scar of the tributary measuring 4.7 Km. has been interpreted near Meharban village using high resolution satellite data (Cartosat-I) for the year 2006. It seems like an Oxbow lake, partially filled with water at certain places. (Fig. 7).



Fig. 7. Area of oxbow-lake converted into agricultural land

Field surveys conducted near village Meharban in a stretch of an area of 7.4 Sq Km. shows the complete blockage of the paleochannel (Fig. 5). The paleochannel is converted into an oxbow lake (which can also be said as meander scar) due to encroachment and obliterated at certain places. Some portions of the paleochannel have been converted into agricultural land (Fig. 8).

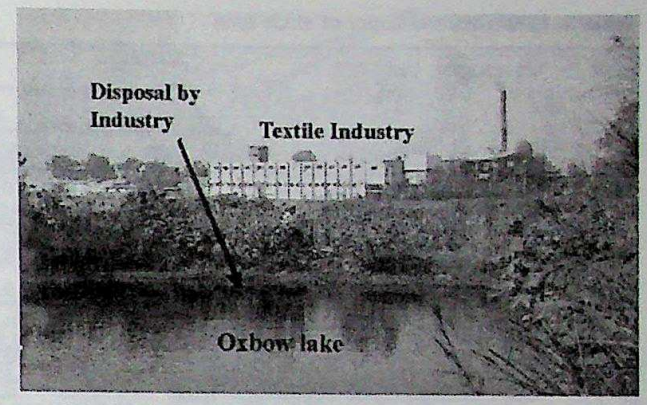


Fig. 8. Discharge of effluents into oxbow-lake by textile industry on its bank

Various Chemical industries, mostly dying and textile have also been set up near the Oxbow-lake which are disposing high quantity of effluents (dissolved and undissolved suspended material) into it without effluent treatment plants (Fig. 11).

Impact of industries on groundwater quality

Textile industries are the main source of pollution. Some of the common salts found in groundwater of the area near meander exceed the normal prescribed limits. The quantity of the salts in drinking water may cause adverse affects on the health system when they become higher than the permissible limits (Table 4).

People of the area have already discarded hand pump water for drinking on their own. Samples (Table.5) which were taken very close to the meander have shown high concentration of these soluble salts. Out of these, Sample No.7 (Table 6.4) surface water taken from the meander itself is highly polluted, shows EC 2.5 dSm^{-1}, which is very much higher than the permissible limit (0.8 dSm^{-1} at 25ÚC), and shows the high content of dissolved solids.

The quantity of these effluents in the groundwater decreases with increase in depth of the source as well as by moving away from the meander as in sample numbers 1, 4, 9, 10, and 11 (Table 6, 4).

The study shows that the remote sensing and GIS techniques are very useful in the identification, delineation and mapping of both natural and anthropogenic activities to monitor the temporal changes. The haphazard growths of colonies have obliterated the most prominent drain and on the other hand, increase of industries in the area has polluted the surface water of the drain. This resulted in the degradation of groundwater quality.

The paleochannel which was a good source of water, has now become a major problem due to rapid urbanization and set up of industries along its banks, giving rise to various

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Table 3. Land use/land cover of study area

Year	Geomorphic Unit	Land Use/Land Cover				
		Area in sq km & (% age)				
		Built up	Forest	River/Stream	Agriculture	Total
1960	Flood Plain	1.75 (0.57%)	8.23 (2.70%)	74.0 (24.34%)	219.96 (72.36%)	303.94
	Alluvial Plain	20.29 (7.55%)	———	———	248.45 (92.44%)	268.74
	Total	22.04	8.23	74.0	468.41	572.68
2006	Flood Plain	58.35 (19.19%)	9.18 (3.02%)	13.67 (4.49%)	222.74 (73.28%)	303.94
	Alluvial Plain	183.80 (68.39%)	———	———	84.94 (31.60%)	268.74
	Total	242.15	9.18	13.67	307.68	572.68
F.P	%age Change (1960-2006)	18.62	0.32	-19.85	2.78	
A.P	%age Change (1960-2006)	60.84	———	———	-60.84	
	Total %age	38.43%	0.16%	-10.53%	-28.06%	

Table 4. Diseases caused by increasing salt concentration in water

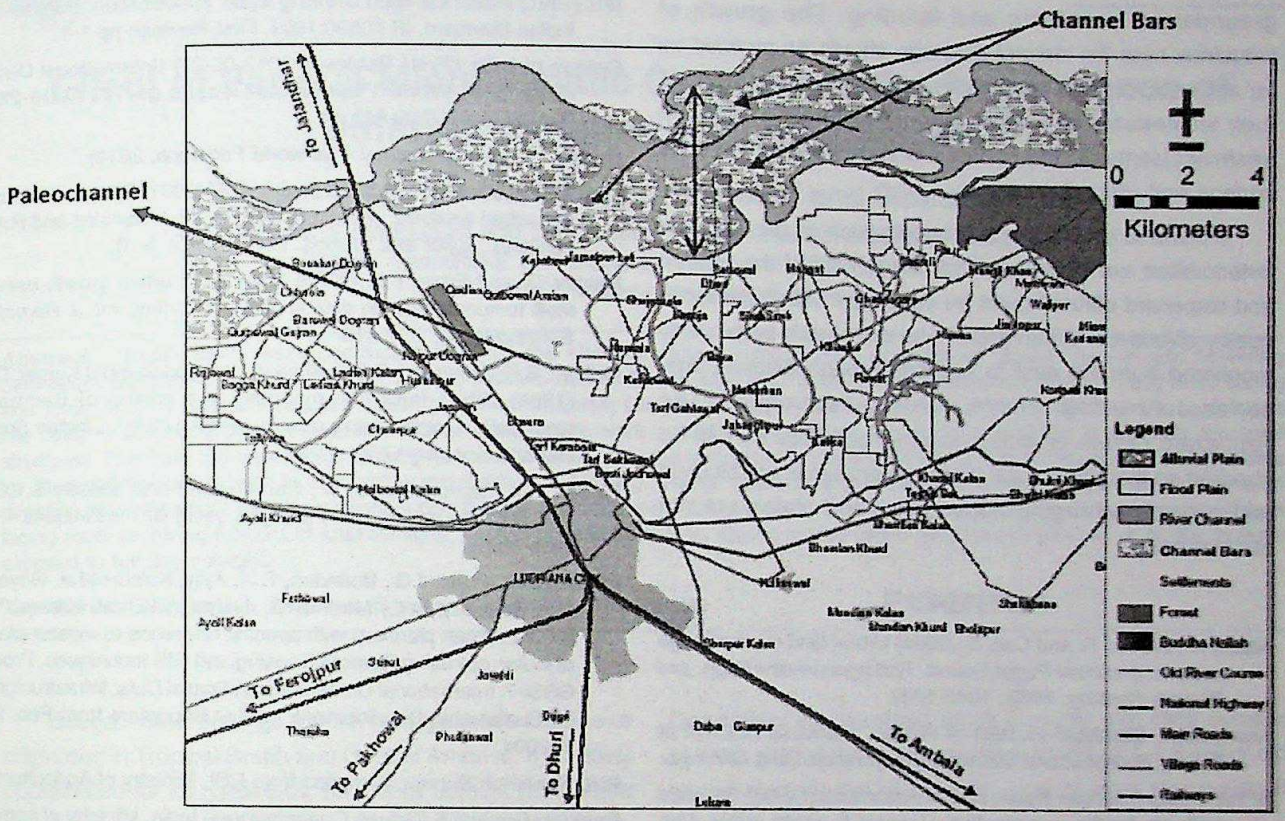
S.No	Parameters(Units)	BIS Prescribed LimitsIS : 10500,1991		Probable effects
		Desirable Limit	Permissible Limit	
1	Total Hardness$CaCO_3$,(mg/l)	300	600	Calcification of arteries, may cause urinary concretions, diseases of kidney or bladder and stomach disorder
2	Chloride (mg/l)	250	1000	Taste, indigestion, corrosion and palatability are affected. Injurious to people suffering from heart and kidney disorders
3	Calcium (mg/l)	75	200	Causes concretions in the body such as kidney or bladder stones and irritation in urinary passes
4	Magnesium (mg/l)	30	100	Excess causes laxative effect particularly on new users
5	Nitrate (mg/l)	45	100	High conc. causes gastric cancer and adversely affects central nervous system
6	Sodium (Na)(mg/l)	No Guideline		Harmful to persons suffering from cardiac, renal and circulatory diseases
7	Potassium (mg/l)	No Guideline		Excessive intake is laxative
8	Total Dissolved Solids (mg/l)	500	2000	Palatability decreases and may cause gastro-intestinal irritation

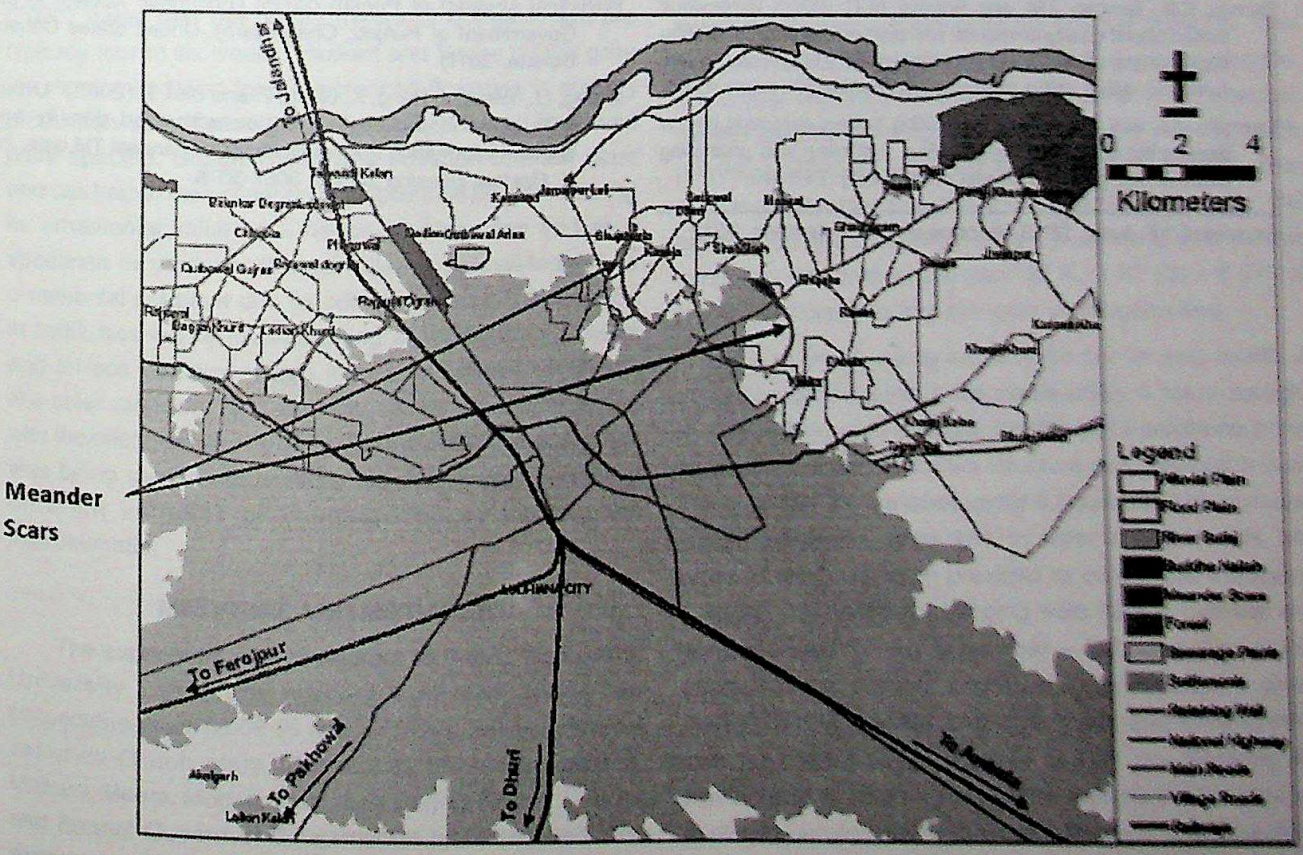
Table 5. Results of Physico Chemical analysis of water samples

Sample No	Source	Depth (meters)	pH	ECd Sm^{-1}	Cations mg/l				Anions mg/l			
					Na^+	K^+	Ca^{2+}	Mg^{2+}	Cal	HCO_3^-	NO_3^-	TH
1	Tubewell	106.6	7.0	0.51	1.83	0.20	38.4	2.11	6.94	313.03	98.5	245.9
2	Tubewell	45.7	6.9	1.02	2.53	0.26	84.5	2.88	83.30	347.80	22.9	433.2
3	Handpump	18.2	6.29	1.75	5.24	0.27	192.3	4.80	62.39	533.31	116.5	878.6
4	Tubewell	76.2	7.0	0.49	1.26	0.03	49.8	1.15	13.82	243.46	15.5	222.1
5	Handpump	36.5	7.17	0.32	0.91	0.12	23.0	0.96	13.82	197.00	9.30	128.7
6	Tubewell	61	7.02	0.45	1.22	0.15	46.0	1.15	13.82	231.87	2.48	210.5
7	Oxbowlake	Surface	7.3	2.50	14.3	0.35	57.7	2.88	500.0	475.34	966.0	351.4
8	Tubewell	67	7.03	0.61	1.39	0.15	53.7	4.04	20.56	231.87	20.46	410.0
9	Tubewell	64	7.05	0.39	0.56	0.12	46.0	0.77	13.82	231.87	20.40	93.36
10	Tubewell	70.1	6.59	0.54	0.16	4.09	57.7	0.76	6.94	324.62	6.2	222.1
11	Tubewell	61	6.70	0.48	0.96	0.02	49.8	1.73	20.56	266.65	17.3	257.5
12	Tubewell	62	7.0	0.62	1.22	0.03	57.71	1.92	26.65	289.84	52.3	292.5
13	Handpump	22.8	7.0	1.42	2.44	0.06	115.4	4.6	212.7	336.22	22.3	632.1

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groundwater problems and flooding. The growth of industries near the natural drainage should be avoided as far as possible. If necessary, the industries should dispose their wastewater only after proper treatment in Effluent treatment plants (ETPs) so that it does not contaminate the surface and groundwater.

If adverse environmental impacts such as groundwater deterioration are to be avoided, the quality of the treated and dispersed effluent must be consistent with local water quality objectives. Urban growth the city should be properly monitored from the past to present through different time series data using remote sensing techniques. The haphazard growth of anthropogenic activities should be checked so that the natural drainage system is not blocked and natural recharging zones like flood plains are not encroached

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Effect of Various Microclimatic Controls on the Performance of Different Varieties of Bougainvillea

Ravipal Singh[1], R.K. Dubey[1]*, V.P. Sethi[2] and Simrat Singh[1]

[1]Department of Floriculture and Landscaping, [2]Department of Mechanical Engineering, Punjab Agricultural University, Ludhiana-141 004, Punjab, India

**E-mail: rkdubey.flori@gmail.com*

Abstract: Experiments were conducted to study the effect of various microclimatic controls on various growth and flowering parameters of different varieties (Mohan, Meera, Mahara, Scarlet Queen, Mrs. H.C. Buck, Thimma, Zakerina, Shubra, Lady Mary Baring and Torch Glory) of Bougainvillea at Punjab Agricultural University Landscape Nursery during the years 2008-10. Microclimatic parameters like solar radiation, light intensity, plant and air temperature were controlled for 4 hours and 8 hours duration in specially designed structures. The main objective of this investigation was to standardize the microclimatic characteristics for different varieties of bougainvillea for their satisfactory growth in different orientations in a building. Meera, Mahara, and Shubra were standardized for east or west direction receiving about 4 hours sunlight during the day. Scarlet Queen, Zakeriana and Thimma were observed to be suitable for buildings facing south receiving 8 hours of total sunlight. Torch Glory and Lady Mary Baring can be grown over terrace gardens or on the rooftops exposed to full day sunlight.

Key Words: Bougainvillea, Direction, Growth, flowering and Microclimate

Bougainvillea belongs to the Nyctaginaceae family and originated in Tropical South and Central America. It is widely appreciated for its hardiness, beauty of both its foliage and colorful bracts and long duration of flowering. In north India, it is planted during July to August. Schoelhorn and Alavrez (2002) found that the bloom cycles of bougainvillea are typically four to six weeks. Hackett and Sachs (1965) gave the recommendation for the increased flowering in nursery production by increasing light intensity through improved plant spacing. Bougainvillea is a pollution tolerant plant and can help in the mitigation of air pollution besides utilizing its ornamental value as a hedge for screening and as a specimen in gardens. Bougainvillea is acknowledged as ornamental pot plant due its colourful bracts. Urbanization in India has led to mushrooming of multistory buildings and terrace gardens, where the environmental conditions like solar radiation, light intensity, temperature vary widely with the orientation the building. So, the present investigation was being carried out to study the flowering behaviour of different varieties of bougainvillea by varying the microclimatic.

MATERIAL AND METHODS

The experiment was carried out at Punjab Agricultural University Landscape nursery, Ludhiana during two consecutive years (2008-09 and 2009-10). Ten experimental varieties (Torch glory, Zakeriana, Shubhra, Thimma, Mahara, Meera, Mohan, Lady Mary Baring, Mrs. H. C. Buck and Scarlet Queen) of Bougainvillea were selected. The experiment was laid under the pattern of FCRD (Factorial Completely Randomized Block Design) with total number of three replications Bougainvillea plants of 1-1.5 years old were transplanted in earthen pots of size measuring 8 inches.

Different varieties were subjected to varying sunlight durations (4 and 8 hours sunlight and full sunlight). The microclimatic conditions were controlled by constructing the 2 specially designed structures in the East- West direction (longer axis) by covering their top and sides with the black polythene sheet for providing the shade to the plants after exposing them to 4 hours and 8 hours sunlight as per the prescribed methodology (Fig 1). Dimensions of the temporary structure (shed) were 25' (L) x 22' (B) x 6' (H1) x 3' (H2), accommodating 450 pots of bougainvillea.

Due to the changing angle of the sun in each month, it was necessary to protect the plants under 4 hours sunlight to extra exposure of sunlight. So, the black polythene sheet on the front of the temporary structure was adjusted in such a way so that the varieties under 4 hours sunlight exposure should not get the extra light. In order to achieve this, two types of hangings were provided to control the exceeding sunlight, the horizontal hanging from April – October and vertical hanging from November – February. The plants under 4 hours sunlight treatment were exposed to direct sunlight during the day time at 9.30 am and were covered with the black polythene sheet at 1.30 pm. Similarly, the plants under 8 hours light duration treatment were exposed to direct sunlight from 9.30 am to 4.30 pm. The potted plants were covered with black polythene sheet afterwards. The

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polythene sheet of each temporary structure was adjusted with the changing angle of the sun every month. Thus all the varieties were given required sunlight and shade exposures. The plants subjected to full sunlight treatment were placed under the open field conditions throughout the day. The temperature of the surrounding air, plant temperature, solar radiation intensity and light intensity of the plants under different sunlight treatments were recorded and interpreted at monthly intervals.

Calculations

The calculations were made and the black polythene sheet was extended accordingly to the changing angle of the sun

$\delta = 23.45 \sin \{360 (284+n/365)\}$ ——————(1)

$W = 15 (T_{solar} - 12)$ ——————(2)

$\sigma s = \text{Sin-1} (\cos \phi \cos\delta \cos\omega + \sin \phi \sin\delta)$ ——————(3)

N= days of year starting from Jan 1 (N = 1 on Jan 1)

T solar= 22.5 degree

ϕ = 30 degree (Latitude of Ludhiana)

W= Clearance width, which is kept in specially designed structure excluding the pot area

From the above equations the calculations were done to increase the hangings month wise so that plants should be not be exposed more than the required sunlight.

There was steep fall in the angle of the sun from Sept. to Dec and onwards there was again rise in the angle of the sun. So, accordingly, the vertical hanging was adjusted.

In the month of Sept.-Oct. and March- April, there was rise in the angle of the sun. So the initial protection of 50 cm horizontal extended polythene sheet was successful in screening the excess incoming radiation. But in the months from Nov.-Jan. there was steep decrease in the angle of the sun as a result a separate black polythene sheet was extended vertically to screen the incoming radiation in these months. The sheet was extended according to the falling radiation in these months.

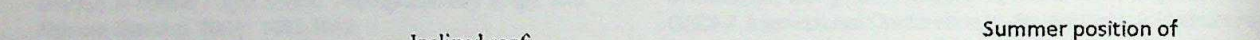


Fig. 1. Side view of specially designed structure showing both the hangings (horizontal and vertical) in different months.

Table 1. Values of Clearance width varies during each month

MONTH	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
d	2.21	-9.599	-18.91	-23.04	-20.91	-12.95	-2.41	-9.414
.as	54.86	45.59	38.05	33.08	37.04	41.30	52.50	61.12
W (cm)	20	38	85	90	94	72	24	40

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Two identical structures were designed for placing the pots in such a way that one of the structures received incident solar light for 4 hrs and the other structure received the light for 8 hrs. The height of the structure towards north side was 230 cm and towards the south side it was 185 cm. Potted area was 675 cm wide and a shaded area of about 50 cm also maintained. Horizontal as well as vertical hangings were provided for providing necessary shade during summer and winter months depending upon the solar altitude angle of the sun as shown in Fig 1.

RESULTS AND DISCUSSION

Significant variation was observed among different varieties of Bougainvillea evaluated for number of bracts per plant on exposure to three regimes of sunshine hours (4hrs, 8hrs and full sunlight). Cultivars Torch glory and Lady Mary Baring recorded 12.92 and 16.35 number of bracts per plant respectively, when exposed to full sunlight conditions during peak flowering season (ie:. March-April). Number of bracts per plant were found to be significantly different with respect to 4hrs and 8hrs sunshine hours exposure in other months as well with maximum number of bracts per plant observed when plants were exposed to full sunlight conditions. During peak flowering season, the solar radiation intensity and light intensity was found to be maximum (529 W m^{-2} and 544 Klux respectively) during the noon which raised the air temperature (33°C) leading to profuse growth anf flowering of Bougainvillea plants. Findings of Munir (2003) also showed that temperature is also one of the most influencing factors for the time of flowering. Torch glory and Lady Mary Baring were found to be best suited for growing on roof tops or on locations exposed to full sunlight.

Zakeriana, Thimma and Scarlet queen exhibited maximum number of bracts per plant when were exposed to 8 hrs sunlight conditions and were found significantly different on exposure to 4hrs and full sunlight conditions during peak flowering season (March-April). Zakeriana, Thimma and Scarlet queen recorded 11.94, 9.91 and 12.33 number of bracts per plant respectively on exposure to 8 hrs sunlight. Significant increase in flowering was observed when the bougainvillea plants were exposed to decreased photoperiodic exposure of 8 hours per day (Jalal, 2009). These varieties were best suited to south facing locations receiving 8hrs of total sunlight for colourful display of bracts.

Shubra, Mahara and Meera were found quiet adaptable to 4hrs sunlight exposures recording 6.05, 8.19 and 8.59 number of bracts per plant respectively. This may be attributed due to low requirement of photo-assimilates for flower initiation. Golstev *et al.*, (2003) reported that extremely high irradiation destroys photosynthetic pigments resulting in the reduction in duration of flowering. Accordingly these varieties were found to be suitable to be placed in east-west facing locations receiving atleast 4 hrs of sunshine hours. The number of bracts per plant decreased correspondingly to increasing sunshine hrs (Table 2).

During cold winter months (Jan-Feb) least number of bracts per plant were counted in all the ten varieties evaluated. This may be attributed due to decreased solar radiation intensity (200 W m^{-2}) as compared to 459 W m^{-2} solar radiation intensity in the month of March inside the shed at same time (Table 5). Light is an essential prerequisite factor for the plant growth and development. It has long been known that photoperiodic conditions bring around the transition from vegetative to productive

Table 2. Effect of interaction between different varieties of Bougainvillea and sunlight exposure on number of bracts per plant

Varieties	Sept-Oct			Nov-Dec			Jan-Feb			Mar-Apl		
	4hr	8hr	Full	4hr	8hr	Full	4hr	8hr	Full	4 hr	8hr	Full
Torch Glory	5.54	6.45	9.50	4.45	5.23	9.55	0.00	0.00	0.00	7.14	8.83	12.92
Zakeriana	5.03	6.95	5.21	3.77	5.78	3.20	0.57	0.63	0.59	9.44	11.94	10.76
Shubhra	1.60	0.91	0.77	5.47	3.09	3.04	5.54	3.00	1.47	6.05	5.41	5.25
Thimma	5.49	7.59	5.46	3.75	5.94	3.84	0.58	5.27	4.19	6.61	9.91	9.19
Lady Mary Baring	3.78	7.27	8.45	6.68	2.10	9.70	0.00	0.00	0.00	8.93	11.93	16.35
H.C.Buck	2.21	2.25	2.45	5.34	1.47	7.17	0.00	0.00	0.00	6.36	6.84	3.50
Mohan	0.36	0.90	0.15	6.29	5.01	3.42	4.83	3.45	2.70	6.19	5.91	5.49
Mahara	3.22	2.73	2.70	8.76	5.35	3.83	6.47	5.41	2.50	8.19	7.72	7.36
Scarlet Queen	3.38	5.80	5.23	2.56	4.47	3.33	0.46	0.56	0.49	8.39	12.33	9.44
Meera	2.45	2.27	2.20	5.84	4.05	3.74	4..69	4.47	2.03	8.59	8.20	7.71
CD (0.05)												
Sunlight x Variety (SV)		0.24			0.32			0.43			0.32	

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development as distinguished from condition that influences the subsequent development of flower buds (Wurr *et al.*, 2000). Studies carried out by Koji *et al.* (2005) reported that low light intensity increased ethylene production that resulted to the preceding reduction of CO_2 assimilation and sugar content, which in turn led to the acceleration of sepal abscission. Air temperature inside the temporary shed was less (1-2 °C) than the average for every month as compared to the outside temperature. The low temperature was due to covering of the shed with polythene sheet after plants were exposed to 4 hours direct sunlight. From the observations recorded it was found that covering the shed, after the plants were exposed to 4 hours sunlight, steep decline in solar radiation intensity was recorded inside the first shed. Observations for sunlight intensity for different duration was also recorded. Solar light intensity was observed to be higher in the months of September and April recorded 960 Klux and 1296 Klux respectively. Light intensities in the months from November-February were found to be lower. This may be due to the frequent rains, foggy whether resulting in decreased sunlight intensity.

Average number of number of bracts per plant on exposure to three regimes of sunshine hours (4hrs, 8 hrs and full sunlight) during peak flowering season were observed maximum in Zakeriana and Scarlet Queen recording 9.26 and 8.11 number of bracts per plant respectively. During April maximum number of bracts per plant were recorded in Lady Mary Baring (13.26) followed by Zakeriana (11.00) and Scarlet Queen (10.09). The number of bracts per plant were found to be significantly different amongst other varieties evaluated. Torch Glory and Thimma each recorded 5.44 number of bracts per plant respectively and were statistically at par with each other but differ significantly from other varieties for exhibiting number of bracts per plant in month of Sept. Torch Glory again recorded (8.89) number of bracts per plant in October followed by Thimma (6.93) but was counted with 9.54 number of bracts per plant next to Lady Mary Baring recording a maximum (12.80) number of bracts per plant in the month of Nov (Table 3).

With respect to sunshine hours exposure (4hrs, 8hrs and full sunlight), number of bracts per plant were found statistically different at 4 hrs and 8 hrs sunshine hrs during the months of Sept-April. However, in the month of Feb, the number of bracts per plant were found at par with each at 4hrs and 8hrs sunshine exposures (Table 4). During peak flowering season, the number of bracts per plant were found to be at par at 8 hr and full sunlight exposures with no significant differences recorded, but differed significantly during the months of Jan-Feb.

Bougainvillea varieties respond differently to varying a microclimatic conditions with respect to solar radiation and light intensity at different months throughout the year. Based on the evaluation studies, Meera, Mahara, and Shubra were

Table 3. Treatments means of Varieties for number of bracts per plant

Varieties	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Torch Glory (V1)	5.44	8.89	9.54	3.29	-	-	6.19	7.78
Zakeriana (V2)	4.69	6.04	6.47	2.05	-	0.99	9.26	11.00
Shubhra (V3)	-	1.10	2.27	3.95	5.05	1.39	5.12	6.84
Thimma (V4)	5.44	6.93	6.88	1.87	0.16	1.19	4.13	7.00
Lady Mary Baring (V5)	3.88	5.55	12.80	3.86	-	-	1.93	13.26
Mrs. H. C. Buck (V6)	-	4.49	9.18	2.53	-	-	6.71	6.88
Mohan (V7)	0.24	0.11	1.30	2.94	3.99	0.73	5.01	5.96
Mahara (V8)	2.44	3.62	4.57	5.57	6.15	1.36	6.00	7.85
Scarlet Queen (V9)	3.72	5.54	5.63	1.06	-	0.92	8.11	10.09
Meera (V10)	1.93	2.65	3.90	4.93	5.47	1.00	6.33	7.54
C.D (p=0.05)	0.31	0.34	0.34	0.31	0.14	0.14	0.16	0.44

Table 4. Treatments means of sunlight duration for number of bracts per plant

Sunlight	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
4 hours (S1)	2.55	4.10	5.56	2.71	1.23	0.48	4.47	5.12
8 hours (S2)	3.15	4.87	6.59	3.61	3.36	1.04	5.82	6.36
Full sunlight (S3)	3.02	4.51	6.61	3.23	1.65	0.75	5.15	6.03
C.D (p=0.05)	0.17	0.32	0.26	0.78	0.13	0.78	0.78	0.44

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Table 5. Different microclimatic controls inside and outside of temporary shed from September- April

Inside the shed				Month	Outside the shed			
Air Temp. (°C)	Plant Temp. (°C)	Solar Radiation intensity ($W m^{-2}$)	Light intensity (Klux)	SEPTEMBER	Air Temp. (°C)	Plant Temp. (°C)	Solar Radiation intensity ($W m^{-2}$)	Light intensity (Klux)
				September				
32.5	32	370 354		9.30 am	32.5	32	370	354
33	33.5	395	401	1.30 pm	34	35.5	849	960
30	28	86.5	108	4.30 pm	31	30	300	300
				October				
27.5	27	300	213		27.5	28	300	213
32.5	33	244	238		33.5	34	700	665
30	28	71.33	82		28.5	27	259	213
				November				
25	26	157	147		25	26	157	147
25.5	26.5	166	152		26.5	28	523	500
23	21	26	41		24	23	137	130
				December				
21	20.5	139	108		21	21	139	108
21.5	22	144	126		22	22.5	498	488
18.0	17	40	40		19	20.5	112	112
				January				
20	20.5	184	136		20	20.5	184	104
21	21	200	144		21.5	22	419	321
19.5	18	59	39		20	19.5	112	98
				February				
22	22	158	140		22	22	158	140
23	23.5	161	151		24	24.5	512	394
20	19	76	83		21	20	217	111
				March				
31	31.5	400	384		31	31.5	415	429
32.5	33	459	400		33.5	35	940	901
26	26	100	110		29	28	388	290
				April				
31.5	31	475	505		31.5	31.5	420	505
32.5	33	529	544		34	36	1000	1296
28	25	124	139		30	27.5	435	429

standardized for their placement in east or west direction receiving about 4 hours sunlight during the day. Scarlet Queen, Zakeriana and Thimma were observed to be suitable for buildings facing south receiving 8 hours of total sunlight whereas Torch Glory and Lady Mary Baring can be recommended for placement over terrace gardens or on the rooftops exposed to full day sunlight.

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Feeding Ecology and Habitat Use of Sloth Bear (*Melursus ursinus*) in Jassore Wildlife Sanctuary, Gujarat, India

Darshan Sukhadiya, J.U. Joshi[1] and Nishith Dharaiya

Department of Life Science, Hemchandracharya North Gujarat University, Palan-384265, Gujarat, India
[1]Deputy Conservator of Forest, Kheda, Gujarat, India
E-mail: nadharaiya@gmail.com

Abstract: North-Eastern Gujarat is known for its high density population in India. Local community around the forests is mainly depending upon the local forest produces and sharing many resources with the wildlife lives therein, which seldom results in the human-wildlife confrontation and conflicts. The present study has been carried out to know the food composition of Sloth bear in the area and the seasonal variation in their diet composition. Scat analysis technique was employed to know the food of Sloth bear in different season along with the sign survey to know the habitat use. The scat study revealed that a sloth bear in the area chiefly consumes fruits of five plant species, followed by termites, ants and bees. No any significant seasonal variations in food composition of Sloth bear were found; however high consumption of termites and ants (79.3%) recorded during monsoon and winter, while in summer the bear mainly depends on the fruits. Among the fruits, *Zizipus* species appear to be important food resource (62.67%) for bear in the study area, especially in dry season when fields lack crops and other fruiting plants. Moreover ground configuration is hard, making it difficult for bear to dig for ants and termites.

Key Words: Sloth bear, feeding ecology; seasonal variation; scat analysis; Jassore Wildlife Sanctuary

Sloth bears are reported to exist in 174 protected areas in India, which includes 46 National Parks and 128 Wildlife Sanctuaries (Chauhan, 2006). In the State of Gujarat, India, bears are reported in five protected areas Shoolpaneshwer Wildlife Sanctuary, Jambughoda Wildlife Sanctuary, Ratanmahal Wildlife Sanctuary, Jessore Wildlife Sanctuary and Balaram Ambaji Wildlife Sanctuary. Jessore Wildlife Sanctuary, the area of present research work is located in Banaskantha district of Gujarat. The Sanctuary has reported some of the highest Sloth bear densities in India (Garshelis, *et al.* 1999). The Sloth bear declared as Scheduled - I animal as per Indian Wildlife (Protection) Act (1972) and critically endangered as per IUCN. The major aim of the present research is to study the food and feeding ecology of Sloth bear in the study area and to know the habitat use by Sloth bear.

Very few studies have been carried out on sloth bear, their ecology and habitats in Gujarat. According to Dharaiya (2009) food is one of the important resources which is shared by both human and bear in north-eastern Gujarat and might be one of the reasons for creating circumstances for human-bear interactions. The study has been carried out during November 2010 to October 2011. The findings of the present study on food composition of Sloth bear and its seasonal variation may be helpful to understand the requirements of food resources for Sloth bear in different habitats of the study area.

The present study area in the Gujarat falls under the semi arid region; however, the area has sparse and scattered forest cover. The study area is declared as a wildlife sanctuary mainly to protect the Sloth bear as a flagship species. Survival of Sloth bears depends on availability of suitable habitat along boulder and rocky outcrops in forest areas. People invade forests and share natural resources, which result in increasing competition and confrontation. Although the sanctuary has reported with highest bear population, the optimum habitat that can support such a large population is completely lacking (Mewada, 2010).

Further the increasing bear-human conflicts and escalating bear attack on humans in the area demands some systematic scientific study on different aspects of bear ecology which can be helpful in mitigating bear-human conflicts and encourage conservation of bears and habitats.

MATERIAL AND METHODS

Jassore Wildlife Sanctuary is specially established for conservation of the Sloth bear and its habitats and is located between 24.20° N and 72.30° E in Banaskantha district of Gujarat state (Figure 1). Jassore is a part of the Western Arawali mountain ranges composed of a contiguous and vital patch of habitat for variety of wildlife and a rich floral diversity. The total area of the Sanctuary is around 180 km^2. Two main rivers, Banas and Sipu flows generally during monsoon and post monsoon season but almost dries up during the hot summer. Geographically the area has rugged hills covered with dry deciduous forest, while flat terrine

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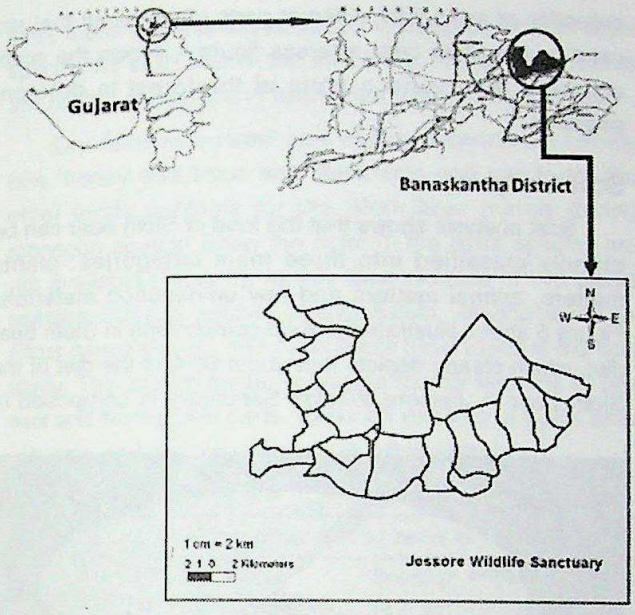


Fig. 1. Map showing the Jassore Wildlife Sanctuary

harbors thorn and scrub forest types.

The Sloth bear is a flagship species of the sanctuary; however it also harbors a good population of Leopard (*Panthera pardus),* Striped Hyena (*Hyaena hyaena)* and other wildlife. The previous study revealed that there are more than 400 species of plant, 212 species of bird and 25 species of mammals are also occurring in their natural habitat (Dharaiya, 2008).

Among the flora, the area has varied composition of Plants; the main plant species are *Commiphora wightii* (Gugal), *Bombex Ceiba* (Simalo), *Cassia auriculata* (Aval), *Cassia fistula* (Garmalo), *Diospyros melanoxylon* (Timaru), *Zyzypus mauritiana* (Boradi), *Butea Monosperma* (Khakharo).

The surrounding forest area is affected from very high biotic pressure and immense human activities such as mining, development of roads and agriculture, industrial development and high tourism and pilgrimage.

The nocturnal foraging habits of Sloth bears primarily do not permit adequate data to be gathered based on direct observation on their feeding behavior. Feeding ecology of Sloth bear mainly studied by the scat analysis, one of the widely used techniques to study the diet of large carnivores. Scat analysis is also described as the one of the best available methods for studying the food habits of Sloth bear (Dharaiya, 2009, Mewada, 2010).

Sloth bear scats were identified and collected from different parts of the Sanctuary according to the divisions made by the forest department. The scats were collected on seasonal bases and efforts have been made to collect equal number of scats in each season. The scats were collected in polythene zip locks and marked with collection details such as location, time, date, etc.

Scats were sun dried in the field and brought to the laboratory for the analysis. Dietary composition through scat analysis has been widely studied on different bear species. In some studies on Black bear, both scats and stomach contents have been used and in few other cases, only food remains have been used to know the food composition of bears

Analysis has been done as described by Bargali (2002), and many others (Maehr and Brady, 1984; Mace and Jonkel, 1986; Gokula *et al.*, 1995). Scats were weighed separately and each scat was washed for further analysis. Entire scat samples were kept in beaker and soaked with water for volume measures. Following this, scat samples were washed in running water and passed through sieves of the size of 0.7 mm and 0.4 mm. Remaining portions of the scats were kept in petri dish for oven drying for 15-24 hrs at 60 °C. Then the scats were analyzed manually by separating food remains such as ants, termites, fruits seeds etc. All inseparable and unidentifiable crushed matter including insects and fruits were considered as unidentified matters.

Dietary composition was estimated in terms of frequency of occurrence of food item in the scats and percent dry weight of each item were calculated. Variation in food composition in different seasons like summer (March-June), monsoon (July-October) and winter (November-February) were also studied using statistical tests like X^2 test and correlation analysis.

RESULTS AND DISCUSSION

Total 54 transects of 2 km each was walked throughout the study area and 96 scats have been collected during the field work of 12 months.

Sign Survey

Sign survey is important part of this study to know the distribution and habitat use of Sloth bear. Figure 2 shows the number of Sloth bear signs recorded on the transect walk during the different season in the Sanctuary. Maximum signs were recorded as scats and the pugmarks of Sloth bears in all the areas. Maximum numbers of signs were recorded from the Manpuriya (Dense forest) area, this part of the sanctuary is dominated with *Casia* and *Zizyphus* species, both the dominant plant species are providing food for the bear in cold season. Following to Manpuria (Dense forest) area, almost same numbers of signs were recorded from the rest of the forest areas; however no bear sign has

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been recorded from the forest patch known as Khara (*Prosophis* forest) forest area. Forest patch of Khara is chiefly dominated with *Prosophis* and this seems to be a reason why bear signs have not been recorded from this part of the forest. Looking to the seasonal variation of sign encounters in different forest parts, the figure depicts that there is no any seasonal variation with respect to the sign encounter in different forest part (Figure 2).

Scat Sample Collection

Total 96 scats were collected during entire study and through different seasons. Figure 3 shows the season wise collection of scats from different parts of the forest that are used by the Sloth bear whereas figure 4 shows the scats collected from various parts of the forest in different seasons.

Scat Analysis

Scat analysis shows that the food of Sloth bear can be broadly classified into three main categories: plants matters, animal matters and few unidentified materials. Figure 5 above illustrate the food composition in Sloth bear diet, which clearly depicts that about 50% of the diet of the Sloth bear in Jassore Wildlife Sanctuary is composed of

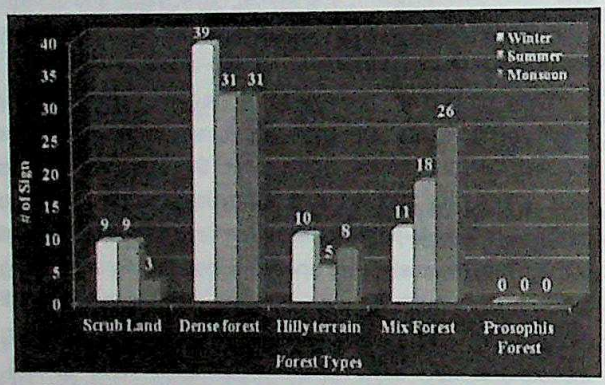


Fig. 2. Bear signs recorded in different parts of the forest during three different seasons



Fig. 3. Total no. of Scat Collected In Different Season

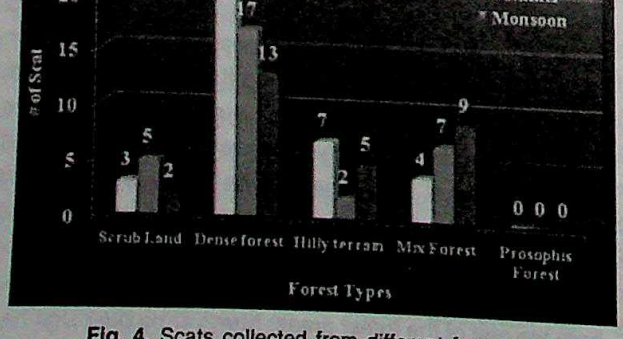


Fig. 4. Scats collected from different forest parts

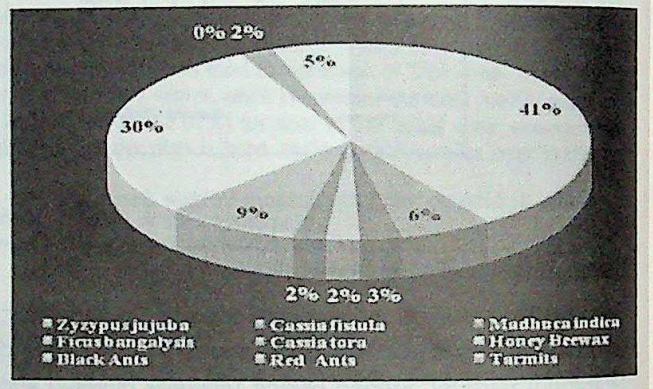


Fig. 5. Food Composition of sloth bear

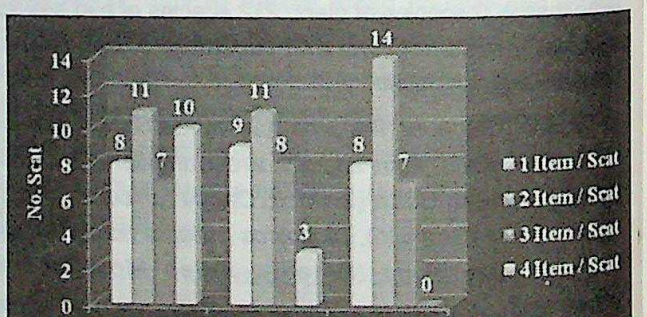


Fig. 6. Multiple Food Item / Scat in Different Season

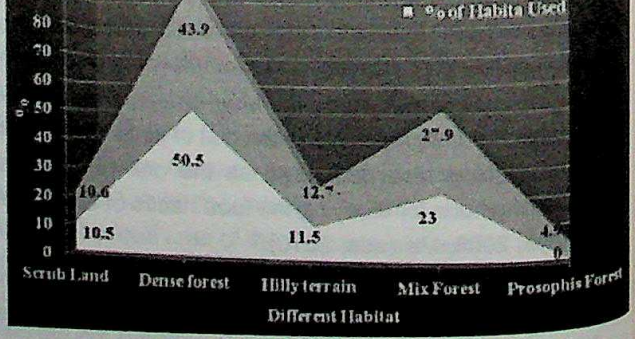


Fig. 7. Food availability and Habitat Use

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plant materials; this indicates the importance of food plant species for sloth bear in the sanctuary. The animal matters are mainly composed of black ants followed by the bee.

Dry deciduous forest type hugely supports the termite hills, honey bee hives and black ants and which are the chief foods contains for the Sloth bear mainly during monsoon season when the fruits in the plant species are not available (Table 1). Mainly food remains of five plants species *Zizypus jujuba, Cassia fistula, Madhuka indica, Ficus banghalensis* and *Cassia tora* have found in the scat study. The animal matter contains mainly remains of bee wax and honey bee parts, chitinous remains of black ants, red ants and termites as well as other insects.

Table 1. Food compositions of sloth bear in different seasons

Food item	% Occurrence of food items in various seasons		
	Winter (n = 36)	Summer (n = 31)	Monsoon (n = 29)
Zizypus jujube	44.96	62.67	7.6
Cassia fistula	4.49	11.5	2
Madhuca indica	4.52	1.86	1
Ficus bangalysis	3.63	2.26	0
Cassia tora	1.44	4.53	0
Honey Bee wax	4.88	5.9	18.6
Black Ants	28.33	7.95	59
Red Ants	0.61	0	0
Termites	1.29	3.33	1.7
Unidentified	5.85	0	10.1

It was also observed in the scat study that a single scat of a Sloth bear may contain multiple food items. Out of 96 scats analyzed, 13 scats containing four food items, 25 scats were found with one food item remained in the scat, 36 scats were containing two food items and 22 scats found with the three food items remained in the scat (Figure 6). In present study we found multiple food items in a scat indicating that a bear might be consuming more than one food items may be due to less availability of food in the area. Figure 6 also shows that highest occurrence of multiple food items do not show any significant seasonal variation ($X^2_{0.05,\,2} = 2.696$) , seasonal variation in multiple species feeding have been recorded in case of large cats in Gir forest by Dharaiya, 2001. No significant seasonal variation in food preference in case of Sloth bear indicates the opportunistic feeding habits of Sloth bear. ($X^2_{0.05,\,2} = 1.352$)

Food avaibility and Habitat use

Moreover, in case of Jassore Sanctuary, bears are found to move in the areas where maximum food is available (Figure 7), which reflects that the food resource is one of the important limiting factors for sloth bear in the study area. Gondaliya (2012) have found significant correlation between the food availability and bear movement in the area. This indicates that conserving and restoring the habitat with the food plants such as, *Zizyphus, Casia, Madhuca, Ficus,* etc. will help in minimizing human-bear conflicts, as bear will not visit the villages if the food is available in the forest areas. Most of the villages are in the proximity of less than two km from the forest boundary that can be easily approached by bear or any wild animals in search of food.

The overall study shows that Sloth bear in the Jassore wildlife Sanctuary are mainly using the forest patches where the food resources are available; the forest part like Khara is almost not used by the bear as the area is completely covered by *Prosophis* which restrict their movement and also the plant or its any part is not used as a food for Sloth bear. Further no significant seasonal food preference clearly reveals the opportunistic feeding habit of the Sloth bear. It can be suggested that planting more food species in the area and on the fringes can restrict the entry of bears in the nearby villages and effectively minimize the human bear interaction in the area.

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Mineral Concentration and their Deviation from Optimum Percentage in *Tribulus terrestris*

Manish Mathur and S. Sundaramoorthy[1]

18E/564, Chopsani Housing Board, Jodhpur-342003, Rajasthan, India
[1]Plant Ecology Laboratory, Department of Botany, JNV University, Jodhpur, India
E-mail: ravi_mm2099@yahoo.com

Abstract: Present investigation was designed to test the effect of spatial factors on deviation from optimum percentage of plant mineral from its reference value in *Tribulus terrestris*. Study was carried out at five natural sites of semi-arid area of the Indian Thar Desert. The potassium, sodium, iron and zinc elements were deficit (negative DOP values). Whereas, DOP value of phosphorus at two sites and calcium at one site showed deficiency. Based on ranking for variations from optimum nutrient concentration sites I and II were similar, requires higher amount of sodium followed by iron whereas remaining three sites requires zinc, potassium and iron in descending order. Principal component analysis revealed that DOP values of various minerals related with edaphic, community and plant metabolite factors. Path analysis exhibited that clay, silt and gravel proportion of soil supports K, Fe and Zn concentration in fruit, respectively. However sand proportion inhibits Fe and Zn. Among primary metabolites total carbohydrate showed negative and quadratic relation with Ca content in fruit. However, among community parameters Shannon and Weaver index for perennials vegetation and Relative Importance Value of *T. terrestris* negatively affects P and Ca content in power and linear path, respectively.

Key Words: DOP Index, Population dynamics, Soil proportions, Thar desert, *Tribulus terrestris*

In any ecosystem, mineral composition of plants is one of its distinguishing features and plays a vital role in its ethno-botanical uses. Thus knowledge of the chemical constituents of plants is valuable in discovering the actual value of folkloric remedies (Aslam *et al.*, 2005), Mineral compositions in a plants are influenced by various factors that associated with edaphic, spatial or site and temporal factors (Mathur and Sundaramoorthy, 2009; Mathur and Sundaramoorthy, 2010). Plant occurs abundantly during rainy season and at filed level early emergence positively related with seedling survival as well as number of fruit\plant (Verdu and Mas, 2006). The major constrains of its production is its poor germination through seed at controlled conditions and their agro-techniques are still not available (Mishra and Shukla, 2009; Tsvetkova, *et al.*, 2011). Georgiev *et al.*, (2010) have concluded that due to extensive collection of *T. terrestris* for commercial purposes by different pharmaceutical companies from natural habitats, resulting in the removal of plants from nature. With the above ample information's the present investigation was designed to test the effect of spatial factors on deviation from optimum percentage of plant mineral from its reference values as well as to try to find out the factors that affects the nutrient concentration in fruit of *T. terrestris*.

MATERIAL AND METHODS

Five natural sites were in and around Jodhpur (Table 1). These five natural sites of different habitats and land uses were selected with the fact that this plant mostly collected from their different wild sources. At each site, 15 plants were harvested and oven dried powdered material were used for analysis._Various macro (Na, K, Ca and P) and micro (Fe and Zn) minerals were quantified by various standards (Jacksons, 1973). The DOP index is defined as the percentage deviation of the concentration of an element (% dry matter basis) with respect to the optimum content taken as the reference value, and it was calculated as

$$DOP = [(Cx100)/C_{ref}]-100$$

Where C is the concentration of a given nutrient in the sample expressed as percentage on a dry matter basis, and C_{ref} is the optimal nutrient concentration percentage on a dry matter basis. The DOP is an index and indicates the relative tendency of nutrient deficiency (DOP>0), optimization (DOP = 0), or excess (DOP>0) in plants (Pereira *et al.*, 2011). The nutritional optima for this area and for this plant had been established previously for nitrogen, phosphorus, potassium, calcium, iron and zinc (Nag *et al.*, 1979; Wealth of India, 2003). These optima have been taken as reference values. The ÓDOP is obtained by adding the values of DOP index irrespective to sigh. The larger the ÓDOP, the greater is the intensity of imbalances among nutrients (Milosevic and Milosevic, 2011). Mineral concentration in soil as well as population dynamics of site largely affects the mineral concentration in plants, therefore these factors helps in assessing the site characterization.

Multivariate Analysis

Principal Component Analysis (PCA) was performed

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Table 1. Characterization of five natural selected sites

Site	N	E	Habitats	Land use	Status
Jalamand (I)	26° 12' 33.7""	73° 4' 8.4""	Sandy Hummocky Plain	Open scrub	Degraded
Bhagat Ki Kothi (II)	26° 14' 31.6""	73° 01' 21.1""	Older Alluvial Plain	Fallow land	Protected with plantation of *Anogeissus pendula*
Kailana (III)	26° 18' 47.0""	72° 60' 35.1""	Piedmonts	Forest	Protected with plantation of *Acacia senegal*
Choka (IV)	26° 17' 2.5""	72° 56' 5.9""	Younger Alluvial Plain	Hill slope	Grazing and cutting allowed
Diger (V)	26° 20' 58.9""	73° 3' 57.2""	Sandy plain	Cropland	Double cropping system followed

to know the relation among DOP values (P, Na, K, Ca, Fe and Zn) in fruit and with various bottom up (community dynamics like, Relative Importance Value {RIV} of *Tribulus terrestris*, Shannon and Weaver Index {H'}, for annuals and for perennials), top down factors like soil parameters (organic carbon, nitrogen, moisture, phosphorus, soil pH and electric conductivity) and primary and secondary plant metabolites like (protein, phenol, carbohydrate, steroidal saponins and alkaloids, Table 2) The interpretation of the correlation circle was carried out under following criteria, when two variables are far from the center, then if they are: close to each other, they are significantly positively correlated (r close to 1); if they are orthogonal, they are not correlated (r close to 0); if they are on opposite side of the center, then they are significantly negatively correlated (r close to -1). Squared cosines were used to link the variable with the corresponding axis and the greater the squared cosine, the greater the link with the corresponding axis. However, in order to determine basic soil, diversity (vegetation) and plant metabolites variables sustaining these interrelationships, the concept of component defining variables (CDV) which stipulates the selection and subsequent naming of variables with the highest component loading (correlation coefficient) as variables that provide the best relationships (Iwara, 2011) was employed.

Table 2. Bottom-up, top down and community factors uses for principal component analysis

Parameters	Range
Soil parameter	
Clay	27.61-33.35
Silt	3.63-21.87
Sand	20.37-63.04
Gravel	2.765-19.84
Electric Conductivity (mScm^{-1})	0.143-0.465
Organic Carbon (mg 100 g^{-1})	151-218
Nitrogen (mg 100 g^{-1})	3.73-37.05
Phosphorus (mg 100 g^{-1})	21.38-54.06
Moisture (%)	7.5-18.3
pH	7.75-8.43
Plant metabolites	
Carbohydrate (mg g^{1})	44.1-83.01
Steroidal Saponin (i g g^{-1})	0.54-10.0
Alkaloid (%)	2.37-3.9
Phenol (i g g^{-1})	10.77-13.5
Protein (mg g^{1})	0.157-12.06
Community Parameters	
Shannon and Weaver (H') Annuals	0.3-1.48
Shannon and Weaver (H') Perennials	0.23-2.06
Relative Importance Value of *T. terrestris*	20.61-36.72

Path Analysis

To find out the factors that affects the nutrient concentration in fruit of *T. terrestris* appropriate regression equations were selected on the basis of probability level significance and higher R^2 value. This path analysis was carried out with Curve Expert software.

RESULTS AND DISCUSSION

Phosphorus concentration ranges from 2.03 to 3.10, calcium 1.30 to 1.61, potassium 0.68 to 1.69, sodium 0.06 to 0.08, iron 0.08 to 0.13 and zinc concentration ranges from .003 to 0.019 (Table 3). Inorganic profiles of *T. terrestris* from two different locations at Pakistan have been carried out by Hussain *et al.*, (2011). According to them variability in various inorganic properties were brought by both modular and spatial factors. Shaheen *et al.*, (2012) correlate the diuretic effects of this plant with higher concentration of potassium salt.

DOP values of various macro and micro nutrients reveled that fruit from all the sites showed deficiency of K, Na Fe and Zn (negative DOP values), however, *Bhagat Ki Kothi* and *Chokha* sites for P and Diger site for Ca showed deficiency (Table 3). According to ÓDOP index Chokha>Diger>Kailana>Bhagat Ki Khothi sites showed wider imbalance in nutritional values, whereas Jalamand site showed lower intensity of imbalance among nutrients. The variations in DOP values of various nutrients in fruit of *T. terrestris* largely contributed by site factor at 99% probability level (Table 3). Based on the DOP values, mineral requirement of Sites 1 and 2 were similar and requires

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Table 3. Mineral composition (Percentage) and DOP values in *T. terrestris* fruit at different sites

Site Name	P		Ca		K		Na		Fe		Zn		
	%	DOP	%	DOP	%	DOP	%	DOP	%	DOP	%	DOP	ΣDOP
Site I	2.67	6.8	1.61	12.04	0.68	-83.63	0.08	-98.72	0.13	-42.89	0.03	-14.04	220.44^{f}
Site II	2.03	-18.8	1.54	7.031	1.69	-59.61	0.06	-62.00	0.18	-48.69	0.019	-57.32	239.40^{e}
Site III	3.10	24.32	1.48	2.81	1.16	-72.32	0.06	-60.23	0.08	-61.06	0.004	-91.25	257.73^{c}
Site IV	2.38	-4.66	1.56	8.83	1.22	-70.91	0.06	-60.5	0.08	-61.7	0.007	-83.77	272.77^{a}
Site V	2.51	0.46	1.30	-9.70	1.49	-64.41	0.08	-47.37	0.11	-52.12	0.003	-92.17	265.32^{b}
Average	2.54	1.62	1.50	4.20	1.25	-70.17	0.07	-65.76	0.12	-53.29	0.013	-67.71	251.13^{d}
CD (p=0.05)	-	7.064	-	5.25	-	14.25	-	6.59	-	8.38	-	5.74	

higher amount of sodium followed by iron whereas, remaining 3 sites requires zinc, potassium and iron in descending order.

Principal Component Analysis (PCA)

In present investigation the first four principal components (PC1, PC2, PC3 and PC4) together accounted 100% of the total variance in data set (Table 4) with their individual contribution being 34%, 29.93%, 21.10%, and 14.95%, respectively. On each component, variable with loading e"0.70 were identified as significant variable and used for path analysis and for discussion (Iwara, *et al.*, 2011). Results revealed that among 24 different variables 19 variables were significant. DOP index of Fe and Zn, silt and sand content, EC, carbohydrate and RIV of *T. terrestris* are well correlated with F1 component, whereas DOP index of K and Na, clay, gravel, steroidal saponin, and phenol are well related with F2 component. Among soil parameters phosphorus, moisture and pH are well linked with F3 component, however DOP of P, organic carbon and H' perennials are linked with F4 component. Correlation circle (Fig. 1) revealed that soil texture components like gravel, sand, silt and clay are associated with DOP values of various macro and micro nutrient, Among metabolites total carbohydrate and Ca DOP are related with each other (as located on opposite sides of the correlation bi-plot). H' of perennials and P DOP also showed similar type of relation.

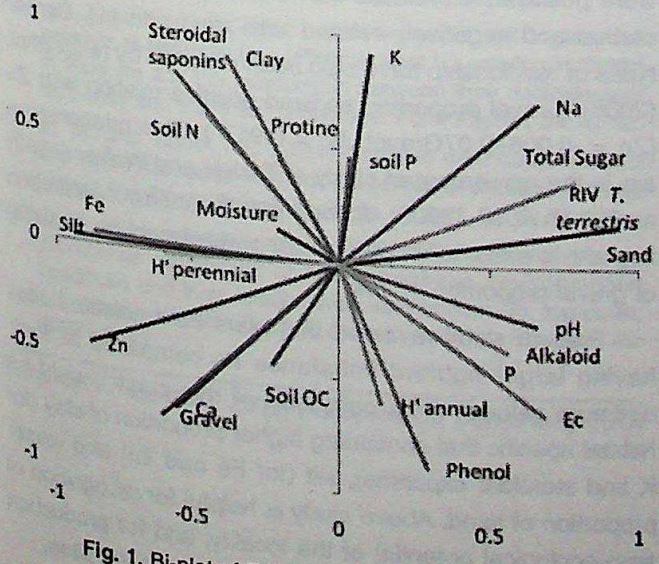


Fig. 1. Bi-plot of Principal Component Analysis.

Path Analysis

Macronutrient

Shannon and Weaver index of perennials showed power and negative relation with P (P = 25.66H' Perennials$^{0.134}$, R^2 =0.851*), while electric conductivity showed quadratic and positive relation with it (P = 22.68+-30.58EC+101.62 EC^2, R^2 = 0.920**). The negative relationship between shrubs/perennial phyto-diversity and P content in fruit of *T. terrestris* revealed poor P acquisition capacity of this plant as compare to their perennial associates. Brocque and Buckney (2003) have uses shrub diversity as a predictor for nutrient concentration in many sclerophyll and mesophyll plants. Positive relations between EC and P content in lettuce plant have been reported by Mohammad and Athamneh (2004).

Clay proportion of the soil revealed linear and positive relation with K (K= -28.18+1.37 Clay, R^2= 0.845*). Positive relation between K content in plant and clay contents in soil have been reported by Kizilgoz *et al.*, (2001). In general the overall sorption of K depends on clay contents and its mineralogy composition (Blake, *et al.*, 1999). However, gravel proportion of soil showed negative and quadratic relation with K concentration in fruit (K = 13.82+0.160K+-0.02K^2, R^2 = 0.834*). In our study PCA analysis revealed that Clay content not only related with K in fruit but also it relates with steroidal saponins, an active natural product (Figure 1). Path analysis revealed that clay content positively and significantly related with steroidal saponin in exponential manner (Steroidal saponin = 40.37e$^{0.09\ Clay}$, R^2 = 0.933**). This finding is also supported by one of our earlier studies (Mathur *et al.*, 2008), wherein relationships' between clay proportion of soil, K mineral, and steroidal saponin in *Corchorus depressus* were established.

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Table 4. Eigenvalue,% cumulative variance and other parameters obtained from PCA

Parameters	F1	F2	F3	F4
Eigenvalue	8.161	7.185	5.064	3.590
% variance	34.004	29.936	21.102	14.958
Cumulative %	34.004	63.940	85.042	100.000
P	0.485	-0.447	0.251	0.708
Ca	-0.552	-0.678	-0.482	-0.042
K	0.105	0.914	-0.336	-0.201
Na	0.659	0.712	-0.202	-0.134
Fe	-0.852	0.056	0.521	-0.018
Zn	-0.867	-0.441	0.230	0.006
Clay	-0.378	0.882	-0.275	0.064
Silt	-0.929	0.032	0.369	0.027
Sand	0.929	0.184	-0.322	0.012
Gravel	-0.605	-0.721	0.330	-0.074
Electric Conductivity (EC)	0.705	0.610	0.226	0.286
Organic carbon	-0.222	-0.451	-0.008	0.864
Soil N	-0.448	0.623	0.595	0.239
soil P	0.035	0.462	0.835	-0.297
Moisture	-0.203	0.140	0.967	0.066
pH	0.655	-0.246	0.703	-0.126
Carbohydrate	0.786	0.380	0.350	0.340
Steroidal saponins	-0.560	0.801	-0.062	-0.201
Alkaloid	0.559	-0.365	0.356	-0.654
Phenol	0.291	-0.871	-0.075	-0.389
Protein	-0.199	0.450	-0.666	0.560
H' annual	0.139	-0.599	-0.620	-0.488
H' perennial	-0.596	-0.012	-0.166	-0.786
RIV of *T. terrestris*	0.732	0.352	0.470	-0.346

Variables underlined with eigenvectors (coefficients) *e"* ±0.70 are considered

With Ca concentration, soil moisture (Ca = 13.35+0.503K+-0.028K^2, R^2 = 0.918**) and total carbohydrate (Ca = 6.84+0.33Total carbohydrate-0.003Total carbohydrate^2, R^2 = 0.926**) showed quadratic and negative relationship. Joham (1957) has concluded that carbohydrate accumulation in various organs has been association with calcium deficiency. On the other hand RIV of *T. terrestris* also exhibited negative and linear relation with Ca concentration (Ca = 19.33+-0.167RIV, R^2 = 0.866*). Thus it indicates that as the dominance of *T. terrestris,* increases the relative Ca contents in fruits decreases.

Micronutrients

Silt proportion of soil showed positive relation with Fe (Fe = 3.22+0.09 Silt, R^2 = 0.98**) and with Zn (Zn = 0.6724+-0.139Silt+0.008Silt^2, R^2 = 0.99**) in linear and quadratic fashion, respectively. On the other hand sand proportion of soil showed reverse relations with Fe (Fe = 6.88+-0.050Sand, R^2 = 0.94**) and Zn (Zn = 2.71+-0.041Sand, R^2= 0.917**) both in linear fashion. The positive relationships of Zn and Fe with silt and negative relationships of these micronutrients with sand were observed by Kumar and Babel (2011). They have found that in wheat grain and straw concentration of micronutrients were positively correlated with silt, clay CEC and organic carbon and negatively related with sand and pH. Similar types of relationship have also been reported by Nazif *et al.* (2006). Gravel proportion showed positive relation with Zn (Zn = -0.006+0.07Gravel, R^2 = 0.917*). This relationships are in the agreement of study of Takkar and Walker (1993) and Singh *et. al.*, (2005), according to them Zn concentration in plant is associated with lesser water retention capacity of gravel proportion of soil.

Present study revealed that plant from selected sites having larger nutrient imbalance as compared to their optimum values. Thus collection of this plant should be habitat specific that containing higher proportion of clay (for K and steroidal saponins), silt (for Fe and Zn) and lesser proportion of sand. Above study is helpful for recognition of agro-ecological potential of the locality, and for production of such plants which are luxuriant only at natural sites.

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Influence of Long-Term use of Fertilizers and Farmyard Manure on the Adsorption-Desorption Behaviour of Sulphur in Soils

P.S. Gill, B.S. Brar and D.S. Benipal*

Department of Soil Science, Punjab Agricultural University, Ludhiana-141004, Punjab, India
**E-mail: dsbenipal@yahoo.com*

Abstract: An understanding of the adsorption-desorption behaviour of sulphate (SO_4^{-2}) in soils after 34 years of long-term fertilization would be an invaluable supplement to our knowledge of the chemistry of (SO_4^{-2}) in soils and would assist in developing (SO_4^{-2}) application strategies for successive crops. With this objective, we collected surface soil samples (0-15 cm) from the agricultural crop land on which a rotation of maize-wheat-cowpea fodder had been grown for 34 years. The soil samples were investigated for adsorption and desorption behaviour of (SO_4^{-2}), supply parameters and buffering capacity of soil samples were computed from the sorption data. Sulphate adsorption increased while percentage S adsorbed decreased gradually with increasing levels of added sulphur (SO_4^{-2}). Bonding energy constant (K) and Freundlich constant (n) decreased with S application. The adsorption and desorption of applied (SO_4^{-2}) were inversely related and the soils that adsorbed the most readily released it the least into the soil solution and vice-versa. Application of S decreased maximum buffering capacity and increased (SO_4^{-2}) supply in soil. Various adsorption-desorption parameters were significantly related with (SO_4^{-2}) uptake of maize and wheat crops. Adsorption maxima, desorption maxima, supply parameter and maximum buffering capacity are the major parameters governing S availability in soils.

Key Words: Adsorption, Buffering capacity, Desorption, Sulphur, Farmyard mannure

Sulphur deficiency in soils of tropical and subtropical regions has been recognized for many years (Pasricha and Fox, 1993). Depletion of soil S reserves occurred due to intensification of agriculture with high yielding crop varieties and multiple cropping, use of high analysis S-free fertilizers and restricted use of organic manure (Sakal and Singh, 1997). The increasing demand for and escalating cost of S fertilizers during the last decade have increased interest in the development of technology for more efficient S fertilizer use, to increase S fertilizers efficiently in different soils an understanding of the S transformation in relation to its availability to crops is required. Sulphur availability in soils for crops depends on interaction of sulphate with soil matrix. Sulphate sorption by soils, being affected by various properties viz; pH and presence of complexing anions (Prafitt, 1982), extractable Fe and Al (Johnson and Todd, 1983: Fuller *et al.*, 1985), organic C (Inskeep, 1989), soil horizon type (Johnson and Todd, 1983), Ca^{++} and K^{+} ions (Bahl and Pasricha 1984), $CaCO_3$ content (Bhogal *et al.*, 1996), phosphate concentration (Ensminger, 1954 and Kamprath *et al.* 1956) and water and phosphate extractable sulphate (Reddy *et al.*, 2001). Sulphate adsorption is an important property of soil that retains sulphate against leaching and controls its availability to plants. Various isotherms (Langmuir, Freundlich and Temkin) have been used to study the adsorption behaviour of S in a soil system to get an idea of the adsorption capacity as well as the energy with which the nutrient is retained in the soil system. Many researcher workers have investigated a wide variety of soils collected from different locations. However, investigation on long-term fertilizers experiment soils after fertilization for more than three decades are lacking. Such studies may be helpful for formulating S application strategies for successive crops. The objective of investigation reported here were: (1) to study the S adsorption-desorption behaviour of soils in a long-term fertilizers experiment after 34 years of cropping under maize-wheat crop rotation: (2) to correlate adsorption-desorption parameters with S uptake and yield of maize and wheat crops.

MATERIAL AND METHODS

Since 1971 a long-term fertilizer experiment is in progress under maize-wheat-cowpea fodder rotation on a Typic Ustrochrept soil at research farm of Department of Soil Science, Punjab Agricultural University, Ludhiana. The site is located in the Indo-Gangetic alluvial tract at 30° 56/ N and 75° 55/ E, at an attitude of 247 m. a. s. l. Normal rainfall is about 700 mm annually and the water table is below 10 m. The field plot experiment was laid out in a randomized block design with 10 treatments replicated 3 times. For the present investigation 4 treatments were selected out of the original 10 treatments. The details of these 4 treatments are given in Table 1. The fertilizer rate were given to crops in the rotations as worked out on the basis of initial soil test values determined at the beginning of the experiment. Rates are expressed as a percentage of the optimum rate. Urea, SSP, and Muriate of potash were the sources of N, P, and K,

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respectively, but in the second treatment (S-free) diammonium phosphate (DAP) was used in place of SSP to supply P. In the treatments 3 and 4, S was added through SSP at the rate of 65.4 to 122.5 kg ha^{-1} $year^{-1}$ (Table 1) along with NPK. Whereas, in treatments 1 to 2 no application of sulphur. In the treatment 4, farmyard manure (FYM) @ 10 t ha^{-1} was applied once in a year before maize in addition to 100% NPK. On an average the FYM contained 30% C, 0.66% N, 0.31% P and 0.30% S on a dry weight basis. The important physico-chemical properties of these soils are presented in Table 2.

Sulphur adsorption

Twenty five milliliter of each solution containing 0, 2.5, 5, 7.5, 10, 15, 20, 30, 40, 80 and 160 mg S ml^{-1} soil, respectively as K_2SO_4 was added to 5g soil sample in a series of 50 ml centrifuge tubes. Three replications were kept for each observation. The samples were shaken for 24 hours on a mechanical shaker at 25 $\pm$1°C. Then the samples were centrifuged and filtered through Whatman filter paper No. 42. The concentration of sulphate sulphur in aliquot was determined turbidimetrically using $BaCl_2$ (Chesnin and Yien, 1951). Sorbed S was calculated by the difference between the amount of S added and that remaining in the equilibrium soil solution using the relationship.

$$\frac{x}{m} = \frac{V(Co - Ce)}{g}$$

Where,

x/m = Amount of S adsorbed (mg S g^{-1} soil)

V = Volume of extract taken (ml)

Co = Original concentration of S in solution (mg ml^{-1})

Ce = Equilibrium concentration of S in solution (mg ml^{-1})

g = Weight of soil (g)

The residual soil was retained for desorption studies and adsorption data were analyzed using Langmuir, Freundlich and Temkin equations as described below.

Langmuir equation

The Langmuir equation in its linear form is given by

$$\frac{C}{x/m} = \frac{1}{Kb} + \frac{C}{b}$$

Where,

x/m = Amount of sulphur adsorbed (mg S g^{-1} soil)

C = The equilibrium sulphate concentration (mg ml^{-1})

b = Langmuir adsorption maxima (mg S g^{-1} soil)

K = Langmuir bonding energy constant (ml g^{-1})

A plot of 'C / x/m' versus 'C' gives a straight line. The constant K and b were obtained from intercept and slope, respectively.

Freundlich equation

$$\frac{x}{m} = aC^{1/n}$$

Where,

x/m = Amount of sulphur adsorbed (mg S g^{-1}soil)

C = The equilibrium sulphate concentration (mg ml^{-1})

'a' is the extent of S adsorption (mg S g^{-1}soil) and 'n' is a constant, which is related to rate of adsorption. A linear plot of log x/m versus log C leads to 'a' and 'n' from the intercept and slope, respectively.

Temkin equation.

This equation in simple form

$$\frac{x}{m} = A \ln C + B$$

Where, A and B are coefficients. x/m and C are the same as described in Freundlich equations.

Supply parameter was calculated from sorption data according to equation proposed by Khasawnesh (1971). Differential and maximum buffering capacities were computed from the change in quantity of S adsorbed by the soil due to change in concentration of S in soil solution using relationship given by Holford and Mattingly (1976). The change in the free energy of S adsorbed was calculated by using the following relationship;

$$\Delta G \text{ of sulphate adsorption} = -RT \ln K$$

Where,

R = Universal gas constant (cal mol^{-1} $°K^{-1}$)

T = Absolute temperature (°K)

ln = Natural logarithm

Sulphate desorption

The residual soils obtained from the adsorption studies were shaken with 25 ml of 0.15% $CaCl_2$ solution for 24 h on a horizontal shaker and filtered through Whatman filter paper No. 42.The equilibrium S concentration in the solution i.e. desorbed S was determined by turbidimetrically using $BaCl_2$ (Chesnin and Yien, 1951). Sulphur retained by soil (pre-sorbed S) was determined by taking the difference between initial sorbed S and S in desorption equilibrium solution. The data obtained on sulphur desorption were fitted in accordance with a Langmuir type equation.

$$\frac{D_e}{S_{de}} = \frac{1}{K_d.D_m} + \frac{D_e}{D_m}$$

Where,

S_{de} = Amount of pre-sorbed S (mg g^{-1} soil)

D_e = Amount of S desorbed (mg ml^{-1})

D_m = Desorption maxima (mg g^{-1} soil)

K_d = Desorption constant related to S mobility in soils (ml g^{-1})

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Table 1. Sulphur applied by single super phosphate (kg ha^{-1}) in 34 years and available sulphur status (kg ha^{-1})

Treatments	S applied (kg ha^{-1} year^{-1})		Sulphur applied in 34 years (kg ha^{-1})	Available sulphur (kg ha^{-1})
	Up to 1998	After 1998	1977 to 2005	
Control	0	0	0	19.0
NPK (-S)	0	0	0	13.7
NPK	92.5	65.4	2907.4	34.3
NPK (+FYM)	122.5	95.4	3897.4	44.8

Table 2. Physico-chemical properties of the long-term fertilizer experiment soils

Treatments	pH (1:2)	EC (dS m^{-1})	OC (g kg^{-1})	Sand (%)	Silt (%)	Clay (%)	$CaCO_3$ (%)	CEC (cmol p$^+$ kg^{-1})
Control	7.82	0.16	3.2	84.4	8.3	7.3	Nil	5.2
NPK (-S)	7.79	0.14	3.6	84	8.4	7.6	Nil	6.4
NPK	7.60	0.17	3.6	81.7	9.7	8.6	Nil	5.8
NPK+FYM	7.63	0.26	5.2	83.4	9.3	7.3	Nil	5.9

Desorption maxima (D_m) and constant (K_d) were calculated from slope and intercept of linear plot of D_e / S_{de} versus D_e, respectively.

RESULTS AND DISCUSSION

Sulphur adsorption

The soil samples from the plots that had previously received different rates of fertilizers during the last 34 years differed widely in their sulphate sorption behavior. Following an application of graded level of S (0-160 mg S ml^{-1} soil), the amount of S adsorbed varied between -16 and 162.2 µg g^{-1} soil in (control), -13 to 197.0µg g^{-1} soil in 100%NPK(-S), -22.5 and 109.4 µg g^{-1} soil in (100%NPK) and -16.8 and 100.5µg g^{-1} soil in 100%NPK(FYM) (Table 3). The adsorption of S occurred at higher levels of added S (15, 20, 30, 40, 80 and 160 mg ml^{-1} of S) in all the treatment plots and negative adsorption occurred at the lower levels of S (0, 2.5, 5 and 7.5g ml^{-1} of S) except at 10 mg ml^{-1} level, where control and 100%NPK(-S) showed negative adsorption.

The negative adsorption of S at lower levels was attributed due to light texture soil, which was not capable of holding SO_4^{2-} ion in the clay lattice. At the same time, sulphur from the external sources has not been added for last 34 years. Though, single super phosphate was not sufficient to meet crop requirement for sulphur. Therefore, application of sulphur even at lower rates (0, 2.5, 5, 7.5 and 10 mg ml^{-1} of S) resulted into its recovery in the solution phase to cater to the need of plant instead of moving to the adsorption sites. Setia *et al.* (2005) also reported that sulphur adsorption was positive at higher concentrations (40, 80 and 100 mg ml^{-1} of S) in long-term fertilizer experiment under maize-wheat cropping system.

The amount of sulphate adsorbed increased with an increase in the amount of S added, irrespective of the fertilization history of the soil. Kamprath *et al.* (1956) reported that sulphate adsorption increased with increase in SO_4^{2-} concentration in solution. Murthy (2004) also observed an increase in sulphur content in equilibrium solution in swell-shrink soil. However, the percentage S adsorbed decreased gradually with the increasing levels of added S. This decrease was excepted since the addition of fertilizer S subsequently decreases the electrical potential of the reacting surfaces making them less attractive to more S. Das *et al.* (2004) also reported that the percentage S adsorption decreased with increase in concentration. For example, in 100%NPK (-S) treated soil, when 15 mg S ml^{-1} was added, S adsorption was 26.6 mg S g^{-1} soil, showing a percentage adsorption of 35%. However, when 160 mg S ml^{-1} was added, the corresponding values were 197.0 mg S g^{-1} soil and 25%, respectively. Similarly for the 100%NPK treated soils the percentage S adsorbed decreased from 26 to 14%.

Sulphate adsorption in 100%NPK without S treated plot was strikingly higher than other treatments and minimum adsorption was in farm yard manure treatment (Fig. 1 and Table 3). Higher adsorption can be ascribed to more exchange sites because of the 34 year long stress on the soil S reserves for meeting crop requirements. The available sulphur status of 100%NPK (S) fertilized soil was lower than other treated plots (Table 1), resulting higher adsorption of sulphur. Reddy *et al.* (2003) also reported higher S adsorption in 100%NPK (-S) treated soil than other treatment.

Adsorption of sulphur in the 100%NPK+FYM treated

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Table 3. Amount of sulphur adsorbed (mg S g^{-1} soil) in soils as affected by long–term use of inorganic fertilizers

Treatments	S added (µg S ml^{-1})										
	0	2.5	5	7.5	10	15	20	30	40	80	160
Control	-16.0	-12.5	-7.4	-5.1	14.4(29)	24.7(33)	31.2(31)	45.1(30)	58.3(29)	104.3(26)	162.2(20)
NPK (-S)	-13.0	-10.4	-8.2	-6.7	16.9(33)	26.6(35)	34.0(34)	43.5(29)	65.0(33)	128.1(32)	197.0(25)
NPK	-22.5	-20.5	-7.8	-7.5	-9.1	19.8(26)	24.1(24)	33.8(23)	45.2(23)	86.3(22)	109.4(14)
NPK+FYM	-16.8	-10.0	-11.4	-9.6	10.3	18.8(25)	22.1(22)	31.8(21)	40.1(20)	66.3(17)	100.5(13)

Figures in the parentheses indicates percentage of sulphate adsorption to added sulphate

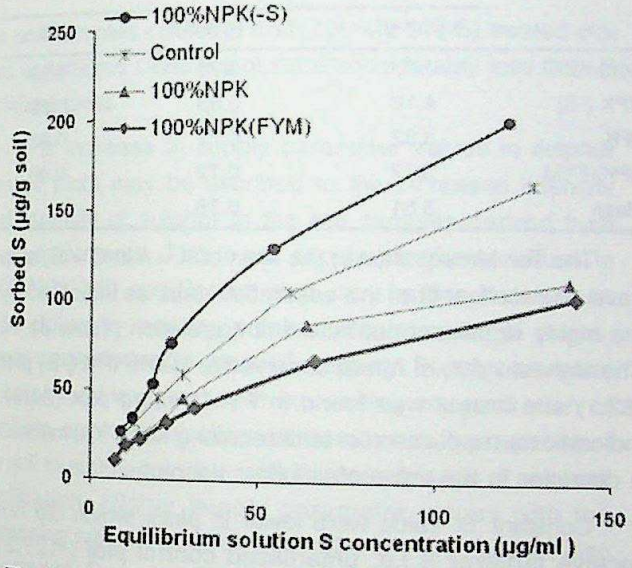


Fig. 1. Sulphate adsorption isotherms of soils of the long-term fertilizer experiment.

plot was lower than 100%NPK treated plots (Fig. 1). This could be ascribed due to blocking of positively charged sites of soils by organic anions or coating of oxides surfaces by organic matter (Couto *et al.*, 1979) and Gobran and Nilsson, 1998). These results get support from Inskeep (1989) who reported that presence of organic acids in soil solution decreased sulphate sorption capacities Das *et al.* (2002) also reported that sulphate adsorption, equilibrium buffering capacity (EBC) and maximum buffering capacity (MBC) increased with the removal of organic matter.

Application of long-term S fertilization caused a considerable reduction in the sulphur adsorption. Reddy *et al.* (2003) also reported reduced sulphur adsorption with continuous application of sulphur during the last 13 years of cropping with finger millet – maize fodder - cowpea rotation.

The sulphate adsorption data for different long-term fertilized soils fitted to the classical Langmuir (R^2: 0.97-0.99) (Table 4). Aggarwal and Nayyar (2001) also reported that S adsorption data can be explained by fitting the data in to Langmuir, Freundlich and Temkin isotherms. Bahl and Pasricha (1984) also reported that Langmuir equation described the adsorption of sulphate from solution by the soils.

The Langmuir S adsorption maxima (b) and bonding energy constant (K) showed a wide variation among soils depending upon the history of fertilization during the preceding thirty four years (Table 4). The values of adsorption maxima, which are a measure of S adsorption capacity of soil, were maximum (285.7 mg S g^{-1}) in the 100%NPK (–S) and minimum in soil receiving 100%NPK+FYM (149.3). Reddy *et al.* (2003) also reported that value of adsorption maxima was higher in 100%NPK (-S) treated soils (161 mg g^{-1}) and minimum (75.8 mg g^{-1}) in the soil supplied with the highest rate of fertilizer S under finger millet-maize fodder cowpea rotation in Kandic Paleustalf. Addition of FYM resulted in favorable effect on S availability in the soil as it decreased the adsorption maxima compared to 100%NPK treated plot (172.2 to 149.3 mg g^{-1}) and this was evident from the increase in concentration of 0.15% ($CaCl_2$) S with the addition of FYM along with 100%NPK. Relationship between adsorption maxima and available sulphur of differentially fertilized soils after 34 years

Table 4. Effect of long-term use of inorganic fertilizers on Langmuir adsorption constants

Treatments	Langmuir parameters			
	b (mg g^{-1})	K (ml mg^{-1})	R^2	DG (cal mol^{-1})
Control	263.2	0.0119	0.99	2623
NPK (-S)	285.7	0.013	0.98	2587
NPK	172.2	0.010	0.97	2683
NPK+FYM	149.3	0.009	0.99	2746
Mean	217.6	0.011		2660

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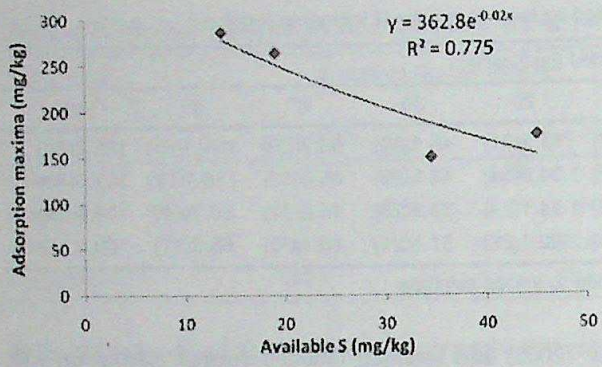


Fig. 2. Relationship between amounts of S adsorbed and the corresponding quantity of S desorbed.

of cropping was worked out. Data in the Fig. 2 revealed that a significant correlation exist between adsorption maxima and available sulphur status (R^2 = 0.775) and showed that adsorption maxima decreased exponentially with increasing available sulphur status of soil.

Bonding energy constant (K), which was a measure of resistance to S release in soils, varied from 0.009 to 0.013 ml mg^{-1}. Highest value K (0.013 ml mg^{-1}) was to be found in 100%NPK (–S), whereas the lowest K (0.009 ml mg^{-1}) was observed in the 100%NPK+FYM treated plot. Results revealed that application of sulphur free fertilizers (100%NPK –S) offers a more resistance to sulphur release in soils and FYM treated plots offers lowest resistance thereby, it releases more sulphur to soils.

Gibbs free energy (DG) varied between 2587 and 2746 cal mol^{-1} with mean value of 2660 cal mol^{-1} (Table 4). Lowest value of DG was obtained in 100%NPK (-S) and maximum in FYM treated plots. Application of fertilizer, compare to control resulted in higher value of DG. An increasing value of DG indicates a decreasing tendency of the soil to adsorb SO_4^{2-} (Das *et al.* 2004). Thus, S adsorption decreased as the value of DG increased from 2623 to 2746 cal mol^{-1} (Table 4).

The sulphate adsorption was fitted well to the Freundlich equation (R^2 = 0-95-0-99). The Freundlich constants i.e. extent of S adsorption (a) and rate of S adsorption (n) also showed a wide variability in the different long-term fertilizer experimental soils (Table 5). Constant 'a' which is a measure of the extent of S adsorption at unit equilibrium concentration ranged from 3.17 to 4.16 mg g^{-1} soil and the value of 'a' was higher in plots (4.16 mg g^{-1} soil), which did not receive fertilizer S i.e. 100%NPK (-S) treatment followed by unfertilized control plot (4.07 mg g^{-1} soil), indicating a depletion of native soil S (Table 5). Continuous cropping without S addition resulted in a greater demand for native soil S in order to meet crop S requirements, thereby increasing the 'a' value.

The Freundlich constant (n) also showed a wide variability in the differently treated plots (Table 5). Rates of S adsorption ranged from 0.72 and 0.83 g ml^{-1}. The 'n' value was highest in 100%NPK (-S) plot (0.83g ml^{-1} soil) and minimum was (0.72 g ml^{-1} soil) in FYM treated plots, respectively (Table 5).

Table 5. Effect of long-term use of inorganic fertilizers on the Freundlich adsorption constants

Treatments	Freundlich parameters		
	a (mg g^{-1})	n (g ml^{-1})	R^2
Control	4.07	0.78	0.99
NPK (-S)	4.16	0.83	0.99
NPK	3.32	0.72	0.95
NPK+FYM	3.17	0.72	0.98
Mean	3.81	0.78	

The Temkin equation in the form of X = A ln C + B, also gave an excellent fit to the adsorption data, as indicated by the highly significant coefficient of correlation (Table 6). A. The highest value of A was observed in 100%NPK (-S) plot (62.1) and lowest was found in FYM treated plot (34.6), indicated that application of fertilizer along with FYM marked a decrease in the value of sulphate adsorption.

Constant 'B' value were lower in plots, which did not receive fertilizer S i.e. unfertilized control plot (-127.2) followed by 100%NPK (-S) (-115.8) treatment (Table 6). Maximum 'B' value was observed in FYM treatment and minimum value of 'B' was in Control plot. These results also suggest that B values increased with sulphate application.

Supply parameter is an integrated expression of quantity, intensity and buffering capacity for sulphate sulphur. These three factors determine the ability of a soil to supply nutrients to the growing roots (Khasawneh, 1971). There existed a highly significant association between reciprocal of equilibrium S concentration and adsorbed sulphur. Supply parameter constant (K_1 and K_2), which correspond to adsorption maxima and bonding energy of adsorption also indicated the same trend as reported earlier for Langmuir adsorption constants in respect of the differently fertilizer treated soils.

The change in supply parameter values in differently fertilized plots is shown in Table 7. Supply parameter value in 100%NPK (-S) long-term soil increased from 0.061 to 0.43 with increasing addition of S from 15 to 160 mg g^{-1} and corresponding values for other soils varied between 0.078 and 0.711 (Control), 0.061 and 0.43 (100%NPK(-S), 0.11 and 0.96 (100%NPK) 0.14 and 1.11 (100%NPK+FYM) treatments, respectively. The supply parameter values in

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Table 6. Effect of long-term use of inorganic fertilizers on Temkin adsorption constants

Treatments	Temkin parameters		
	A	B	R^2
Control	57.6	-127.2	0.93
NPK (-S)	62.1	-115.8	0.96
NPK	38.3	-79.2	0.98
NPK+FYM	34.6	-72.3	0.97
Mean	53.7	-111.2	

the soil samples collected from 100%NPK (-S) treated plot and unfertilized Control plot were considerably less than S fertilized plots.

The increase in supply parameter values in sulphur treated plots may be ascribed to the increased intensity and quantity of sulphur in the soil samples derived from these treatments. The lower supply parameter values in 100%NPK (-S) and Control plots may be due to stress on soil sulphur in meeting sulphur requirements of maize-wheat crops during 34 years of cropping. Supply parameter of sulphate increased with increasing concentration of sulphate sulphur indicating an increase in the capacity of the soil to supply sulphate with increasing levels of sulphate application. Higher supply parameter values with the increasing sulphur addition from different sources had also reported by Das *et al.* (2002, 2004).

Sulphur desorption

The practical reliability of using adsorption isotherms is questionable unless these can be compared with S desorption behavior of the soils. The degree of reversibility of the adsorption-desorption reaction could not be ignored. The relationships between S adsorption and desorption in the long-term experiment soils under investigation were depicted in Fig. 3 and presented in Table 8. It is quite evident that only a fraction of the sorbed S is desorbed. The results show that during the past 34 years the quantity of S desorbed was far less in the 100%NPK (-S) treated plot followed by unfertilized Control plot. The soils that adsorbed a high proportion of applied S during the adsorption reaction tended to release a lower proportion during desorption reaction and vice-versa.

The S desorption data (Table 8) show that desorbed S (D_e), following the application of S, ranged between 6.0 to 64.9 µg g^{-1} soil in Control, 4.0 to 57.8 µg g^{-1} soil in 100%NPK (-S), 9.3 to 75.8 µg g^{-1} soil in 100%NPK and 10.8 to 79.9 µg g^{-1} soil in 100%NPK(FYM). Amount of desorbed S was far less than that of adsorbed S and was of relatively higher order in the treatment receiving 100%NPK+FYM during the past 34 years. Amount of sulphur desorption was maximum in FYM and minimum in 100%NPK(-S) treated plots. Least desorption in 100%NPK (-S) plot may be ascribed due to more removal of native sulphur than any other plots which resulted in high adsorption capacity thereby lowest desorption of sulphur.

The sulphate desorption isotherms depicting the relationship between the S desorbed in the equilibrium soil solution (D_e) and pre-sorbed S (S_{de}) are shown in Fig. 4. It is quite apparent that at any given soil solution

Table 7. Supply parameter of adsorbed sulphur in the soils as affected by long-term use of inorganic fertilizers

Treatments	Supply parameter					
	S added (mg g^{-1})					
	75	100	150	200	400	800
Control	0.08	0.10	0.15	0.20	0.38	0.71
NPK (-S)	0.061	0.082	0.12	0.17	0.32	0.43
NPK	0.11	0.14	0.21	0.27	0.54	0.96
NPK+FYM	0.14	0.18	0.27	0.36	0.70	1.11

Table 8. Amount of sulphur desorbed (mg S g^{-1} soil) as affected by long-term use of inorganic fertilizers

Treatments	S added µg S ml^{-1})					
	15	20	30	40	80	160
Control	6.0(24)	5.9(19)	10.2(23)	15.7(27)	30.9(30)	64.9(40)
NPK (-S)	4.0(15)	5.8(17)	8.5(20)	14.3(22)	35.6(28)	57.8(29)
NPK	9.3(47)	11.6(48)	17.8(53)	24.0(53)	48.8(57)	75.8(69)
NPK+FYM	10.8(58)	14.4(65)	21.5(68)	28.8(72)	50.1(76)	79.9(79)
Mean	7.5	9.4	14.5	20.7	41.4	69.6

Figures in the parentheses denotes percentage of desorbed sulphate to adsorbed sulphate

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Table 9. Effect of long-term use of inorganic fertilizers on Langmuir desorption constants

Treatments	D_m (mg g^{-1})	K_d (ml g^{-1})	R^2
Control	105.3	0.20	0.99**
NPK (-S)	185.2	0.11	0.98**
NPK	48.5	0.14	0.99**
NPK+FYM	25.1	0.17	0.98**
Mean	117.9	0.15	

** Significance at 1% level

Table 10. Differential buffering capacities (ml g^{-1}) of different soils as affected by long-term use of inorganic fertilizers

Treatments	S added (mg S g^{-1}) MBC (ml g^{-1})						
	15	20	30	40	80	160	
Control	13.7	12.1	9.5	6.6	3.2	1.7	3.13
NPK (-S)	17.2	16.0	14.4	11.8	6.4	4.0	3.71
NPK	4.3	3.9	3.0	2.4	1.2	0.7	1.89
NPK+FYM	2.3	1.9	1.4	1.1	0.6	0.3	1.48

Table 11. Relationship of S uptake and yield of maize and wheat crops with the various adsorption and desorption parameters

Parameters	S uptake		Yield	
	Maize	Wheat	Maize	Wheat
B	-0.876**	-0.873**	-0.350	-0.578*
K	-0.712*	-0.749*	0.308	-0.238
MBC	-0.828**	-0.794*	-0.417*	-0.394
A	-0.860**	-0.873**	-0.016	-0.591*
N	0.813*	0.780*	-0.002	0.429
A	-0.816*	-0.784*	-0.012	-0.574*
B	0.859**	0.834**	0.039	0.736*
Supply parameter	0.841**	0.826**	0.562*	0.477*
D_m	-0.714*	0.770*		
K_d	-0.757*	0.725*		

* = Significant at 5% level; ** = Significant at 1% level

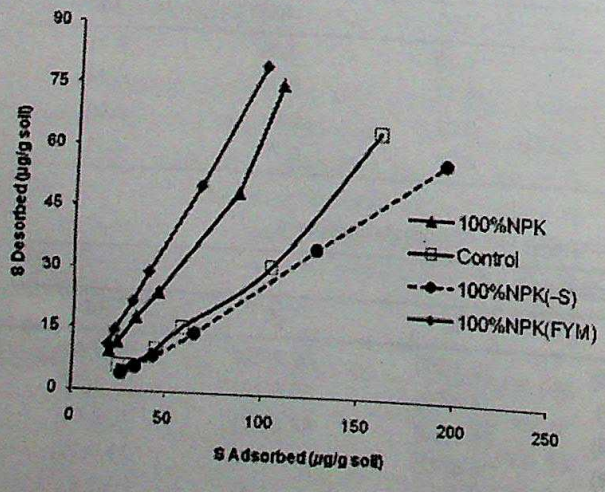


Fig. 3. Sulphate desorption isotherms of the soils in the long-term fertilizer experiment.

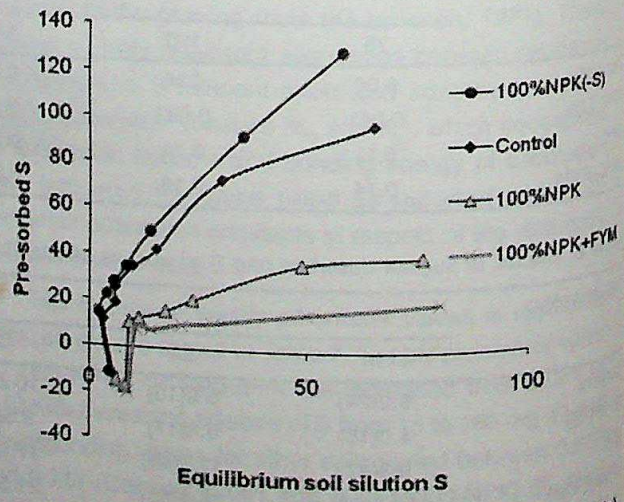


Fig. 4. Relationship between available S status of soils with (a) Adsorption maxima (b) Desorption maxima (c) Maximum buffering capacity.

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concentration, the pre-sorbed soil S (S retained by soil) is present at higher levels in the 100%NPK (-S) soil. Continuous application of fertilizers decreased the pre-sorbed S, with a minimum level reached in the treatment receiving 100%NPK+FYM. The plot of 'D_e' versus 'D_e/S_{de} was linearly correlated for all the long-term fertilizer experimental soils. Desorption parameters (Table 9) obtained from the Langmuir desorption isotherm revealed that desorption maxima (D_m), which indicates the maximum desorable capacity of soil. More the D_m value less is the potential of soil to release sulphur for meeting crop requirements. The maximum D_m value were obtained for 100%NPK (-S) followed by Control treatment. The higher value of D_m in 100%NPK(-S) compare to control plot may be due to lower value of available sulphur in 100%NPK plot due to higher removal of sulphur by crops. FYM treated plot has lower Dm value compare to 100%NPK treated plot thus has a higher potential to release sulphur to meet crop demand. The data thus revealed that the plots receiving continuous S addition over a period of 34 years have more potential to release S for meeting S requirement for the crops, as this was evident from Table 1.

The desorption constant (Kd), which is a measure of the mobility of S in soils, was minimum (0.11 ml g^{-1}) in the 100%NPK(-S), with its value increasing with increased S addition. Continuous addition of FYM resulted in increase the mobility of S in soil (Kd) and thus increased the S supply in the soil.

Buffering capacity

Buffering capacity is the replenishment factor and is an index, which shows the ability of a soil system to replenish the concentration of any given ion into the soil solution when its concentration has been depleted. It is different from the quantity (Q) and intensity (I) term, and Khasawneh (1971) defined as the ratio ÄQ/ÄI. In this sense, the buffering capacity is the resistance offered by a soil system to any change in the intensity (soil solution concentration) term and is related to the energy of dissociation. The agronomic pertinent portion of the Q-I curve in any case (pure system) may be a linear portion of it, but in our complex system of soils a curvilinear relationship was observed for all the soils under investigation (Fig. 1). Thus, buffering capacity is not a constant term, but a variable depending upon intensity. Therefore, differential buffering capacities (DBC) for all the soils were computed from the change in the quantity of S adsorbed by the soil due to change in the concentration of S in the soil solution. The results of these calculations were given in Table 10.

The differential buffering capacities in the 100%NPK (-S) treated long-term soil decreased from 17.2 to 4.0 ml g^{-1} followed by control (13.7 to 1.7 ml g^{-1}) with increasing addition of S from 75 to 800 mg g^{-1} soil; corresponding values (ml g^{-1}) for the other soils varied from 4.3 to 0.7 (100%NPK) and 2.3 to 0.3 (100%NPK+FYM) (Table 10). The differential buffering capacity at all levels of S additions was higher in the 100%NPK (-S) treated plot. The values decreased sharply with S fertilization and were found to be at a minimum in soil receiving FYM. The data clearly indicate an inverse relationship between the rates of S applied (both S added for equilibrium soil in the laboratory as well as the long-term history of S application) and the DBC.

The maximum buffering capacity (MBC) that represents the buffering capacity at the equilibrium solution concentration approaching zero was also calculated. The independence of MBC from solution S concentration makes it the preferable measure of the capacity factor (Holford and Mattingly, 1976) when it is to be combined with other soil S availability parameters. The value of MBC was higher (3.71 ml g^{-1}) in 100%NPK(-S) soil and its value decreased to 3.13, 1.89 and 1.48 ml g^{-1} in the Control, 100%NPK and 100%NPK+FYM treated plots, respectively.

The results presented in Tables 4, 5 and 10 indicate that the soils, with high S adsorptive capacities, had a higher buffering capacity for sulphur. These soils, therefore, would maintain a low supply of S for a longer period compared to poorly buffered soils, which would supply more S but for a shorter time. It is therefore conclude that a high buffer capacity of soil would results in the strong adsorption of the sulphate into onto the solid phase with very little of it in the soil solution for exploitation by plant roots; consequently, the sulphate ion would have a low mobility. Conversely, a low-buffered soil indicated that more of the nutrient would be in the soil solution and that it would have a high mobility. Holford and Mattingly (1976) also found buffering capacity to be inversely related to the ease with which solid phase labile sulphate will move into the solution phase.

Adsorption-desorption parameters and S availability

The values of linear correlation coefficients were worked out between various adsorption-desorption parameters of S and S uptake and yield of maize and wheat crops. Langmuir adsorption maxima (b), bonding energy constant (K), maximum buffering capacity (MBC), extent of adsorption (a), Temkin constant A, desorption maxima (D_m) correlated significantly but negatively with S uptake by maize and wheat crops. The negative correlation values with the adsorption and desorption parameters indicated that as the adsorption of S increased, S became less available resulting low S uptake and low yield. The maximum correlation coefficient for S uptake was found with adsorption maxima (r = -0.876** for maize and r = -0.873** for wheat).

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The relationship between adsorption maxima, desorption maxima and maximum buffering capacity correlated significantly with the available S status of different long-term fertilizer experiment soils is plotted in Fig. 5. The data support a negative correlation between available S content and adsorption maxima (0.910), desorption maxima (0.914) and maximum buffering capacity (0.862) of soils. These parameters decreased exponentially with increasing available S status of the soil. Therefore it is concluded that analyzing soils for their adsorption-desorption parameters is of practical significance and could assist in making fertilizer S recommendation for succeeding crops. The soil having low adsorption maxima, low desorption maxima and a low buffering capacity will require less S fertilization for optimum growth.

CONCLUSIONS

Adsorption-desorption of soils differently treated with fertilizer during a long-term experiment differed widely and were a good index of S availability in the soils. Continuous cropping without S fertilization increased S adsorption and the maximum buffering capacity of the soil and thus decreased S supply in the soils. Application of fertilizer resulted in lower S adsorption compared to other treatments. Highest S adsorption was observed where S was not applied (100%NPK(-S). Sulphur application decreased adsorption maxima and maximum buffering capacity, thus increased S supply in the soils. Consequently, the sulphur application history along with the management practices requires due consideration when formulating S application strategies to successive crops.

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Indian Journal of Ecology

Creation of Inventory of Wetlands in Gurdaspur District using Remote Sensing and GIS

Harpinder Singh, Amardeep Singh, P.K. Litoria and Brijendra Pateriya

Punjab Remote Sensing Centre, Ludhiana-141 004, Punjab, India
E-mail: harpinder13@rediffmail.com

Abstract: The study is aimed at the generation of an inventory of all the Inland Wetlands in Gurdaspur district using multi date IRS-P6 LISS-III digital satellite data. By applying band algebra on the four bands of the satellite data, five indices have been generated namely NDVI, NDWI, MNDWI, NDPI and NDTI. These indices enhance the data, and delineation of water spread, vegetation extent, turbidity information of different categories of wetlands for pre and post monsoon season can be easily done. This spatial information can be very useful for wetland monitoring, management and go as an input to various government projects. When information is presented in a map form, it allows better perception, visualization of spatial patterns and their relationship with the neighboring areas.

Key Words: GIS, Gurdaspur, Remote Sensing, Wetlands

Wetlands contribute to a healthy environment in many ways and act to retain water during dry season, thus keeping the water table high and relatively stable. During flooding they help to reduce flood levels and trap suspended solids and attached nutrients. Wetlands are important feeding, breeding and drinking areas for wildlife. The removal of such wetlands because of urbanization or other factors causes environmental degradation. So there is an increased interest in preparing inventory of the wetlands

The objective of this study is to create an inventory of all the Inland Wetlands in Gurdaspur district using remote sensing and GIS (Geographic Information Systems) techniques. The generated dataset will provide information pertaining to water spread, vegetation extent, turbidity information of different categories of wetlands for pre and post monsoon season. Further, spatial analysis will be done on the combination of the generated dataset with land use and socio economic data to mine useful information.

MATERIAL AND METHODS

The Study area is Gurdaspur district in Punjab. It lies between latitudes of 32° 30' 24" & 31° 36' 13" N and longitudes of 74° 53' 30" & 75° 56' 11"E. It has a geographical area of 3,56,400 hectares. It is bounded by Pakistan in the west, Jammu & Kashmir in the north, Himachal Pradesh in the North east, Hoshiarpur in the east and Amritsar and Kapurthala in the south. Beas river flows in the eastern and Ravi in the north western part (Figure. 1). It has 1659 inhabited villages and fourteen towns. The district headquarters and towns are well connected by transport network.

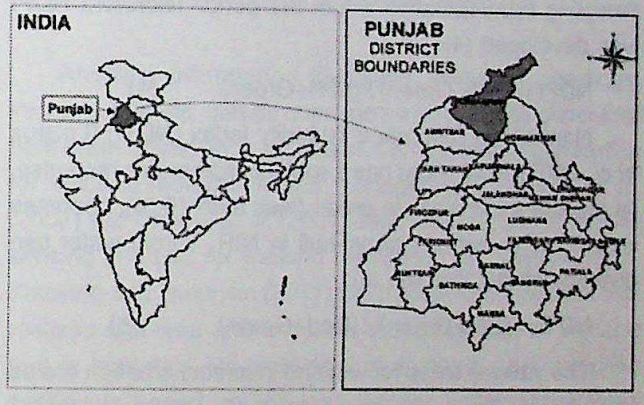


Fig. 1. Study Area

The Spatial data has been extracted from the multi date (pre- and post- monsoon) IRS-P6 LISS-III digital satellite data (spatial resolution 23.5 m, spectral bands MIR, NIR, R, G) using image processing and geographic information systems (GIS) techniques.

In this study, a semi-automatic method has been used to extract the desired features. Five indices (NDVI, NDWI, MNDWI, NDPI and NDTI) have been generated for both pre- and post- monsoon satellite imagery. The combination of these indices enhances the water extent, vegetation and the turbidity, so this information can be easily interpreted and manually digitized. Finally, post and pre monsoon area statistics have been generated for all the wetland categories.

The description of the indices used in the study is as given below:

Normalised Difference Vegetation Index (NDVI) (Tucker *et. al.*, 1986): The vegetation will have positive values and water will tend to have negative values (1).

$$NDVI = (NIR-Red) / (NIR+Red) \quad (1)$$

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Normalised Difference Water Index (NDWI) (McFeeters, 1996): The open water features will have positive values while soil and terrestrial vegetation features will have zero or negative values (2).

NDWI = (Green-NIR) / (Green+NIR) (2)

Modified Normalised Difference Water Index (MNDWI) (Xu, 2006): The reflectance pattern of built-up land in green and NIR is similar to water i.e. both reflect green light more than reflected in NIR. The average reflectance of built-up land in MIR is greater than that of green. Therefore, if a MIR band is used instead of NIR in the NDWI, the built-up land should have negative values (3).

MNDWI = (Green-MIR) / (Green+MIR) (3)

Normalised Difference Pond Index (NDPI) (Lacaux *et. al.*, 2007): The classic NDVI did not perform well for vegetation within the wetland so it cannot be used for detecting the vegetation within the pond. Therefore NDPI was developed (4).

NDPI = (MIR-Green) / (MIR+Green) (4)

Normalised Difference Turbidity Index (NDTI) (Lacaux *et al.*, 2007): Pure water has a specific radiometric response, its reflectance is weak in green (less than 10 %), becomes very small in red and quasi-null in NIR. Turbid water can give signatures like soil (5).

NDTI = (Red-Green) / (Red+Green) (5)

The various steps for wetland inventory creation are as follows (Fig. 2):

1. In the first part, two sets of IRS-P6 LISS-III digital satellite data was acquired for May-2006 (pre monsoon) and October-2005 (post monsoon). Geometric corrections were applied to the images so that these overlaid on each other correctly. The study area i.e. Gurdaspur district was subset from both the satellite images.
2. A model was created in ERDAS Imagine, Image processing software to generate the NDVI, NDWI, MNDWI, NDPI, NDTI images of both the source images by applying band algebra and finally two stacks of indices were created, one for pre-monsoon and other for post-monsoon .(Garg and Patel, 2007).
3. The wetland boundary for pre and post monsoon was visually interpreted in Arc GIS 9.2 environment using the MNDWI, NDPI and NDTI combination from the stack of indices. The union of the vector layers of both seasons was done to get a final extent of all the wetlands.
4. After creation of the wetland boundary, open water spread and vegetation extent of the wetlands was interpreted using the combination of indices from the stack for both pre and post monsoon season. Water extent has been enhanced using MNDWI, NDPI and NDVI bands. The vegetation has been enhanced using NDWI, NDPI and NDVI bands. Turbidity information of the water spread area in the wetlands was interpreted using the MNDWI and NDTI indices images for both pre and post monsoon season.
5. Wetlands less than 2.25 hectares were digitized as a point feature as a separate layer.
6. A field survey was carried out to verify wetland categories and necessary corrections were incorporated after ground verification to finalize the data.
7. The area statistics for pre and post monsoon interpreted data (water spread, vegetation extent) was calculated for all the wetlands.
8. Wetland maps were created using the generated dataset and addition information like settlements, major roads, railway line etc using the same satellite imagery in ArcGIS 9.2 environment.

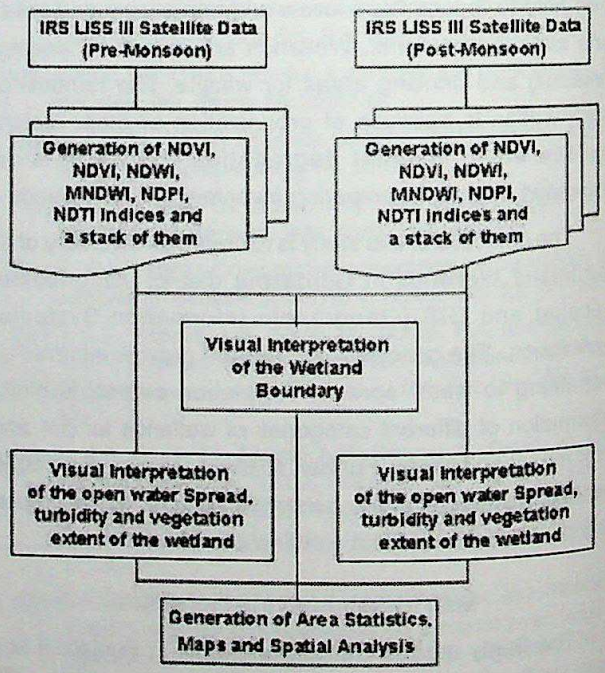


Fig. 2. Methodology

RESULTS AND DISCUSSION

Ninety nine wetlands have been identified in Gurdaspur district (Table 1; Fig. 3) Some important wetlands are Beas River, Ravi river, Keshopur Chhamb, Kahnuwan Chhamb, Magar Mudian Chhamb, Bhopur Chhamb, Kasur Nala and Naumuni Nala. Riverine wetland class has the least area whereas Rivers/Stream covers the maximum area. Beas River has the largest covered area.

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Also, forty eight wetlands have been identified which have an area smaller than 2.25 hectare. These wetlands are lakes, ponds or tanks and have been marked as points in Fig. 3.

The Turbidity information of the water extent of the wetlands has been categorized as low, medium and high. Water becomes more turbid during post-monsoon. The area under water extent having medium turbidity is highest i.e. 3517.29 ha in pre-monsoon and 4269.66 ha in post monsoon whereas the area having high turbidity is the lowest i.e., 1168.30 ha in pre and 1112.07 ha in post monsoon. The area under low turbidity is 1891.53 ha in pre monsoon and 2245.56 ha in post monsoon.

Gurdaspur and Pathankot tehsils have the largest number of wetlands. On creation of a ten kilometer buffer around all the towns of Gurdaspur, it was found that Dinanagar has the maximum number of wetlands nearer to it as compared to other towns. Dinanagar is situated on the national highway and is near the district headquarter. This area can be developed by the tourism department for recreational purposes.

The generated inventory can act as a decision support system for Local/State administration for implementation of wetland development and restoration programmes Use of manual surveying to create this inventory regularly for the whole district will require a lot of resources like time, money and personnel but geoinformatics simplifies the decision making, planning and assessment process and makes it more scientific and cost effective.

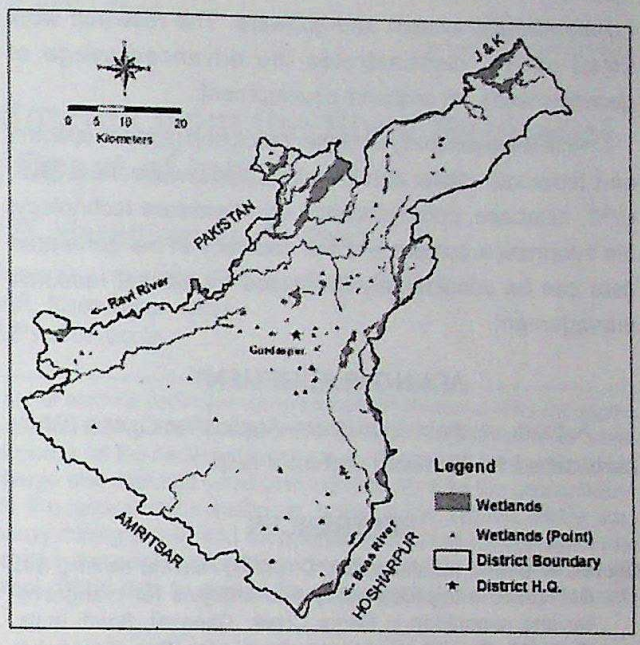


Fig. 3. Wetlands in Gurdaspur District

Ancillary information like soils, elevation, geology, infrastructure etc. can be combined with the data generated from earth observation for analysis and scenario generation for wetland restoration and management. Chaves *et al.* (2007) and Chopra *et al.* (2001) describes the use of remote sensing and GIS for wetland restoration and conservation. Xiaoying and Huanyan (2011) have proposed a system that realizes real-time and accurate sampling data of wetland that is important for protection of wetland. The sampling system is based on wireless sensor network, wireless

Table 1. Wetland classes, number of wetlands, area in hectare (ha) of water extent and vegetation extent for the pre and post monsoon seasons

Wetland classes	No. of wetlands	Area: (ha) (% of total wetland area)	Pre-monsoon		Post-monsoon	
			Water extent (ha)	Vegetation extent (ha)	Water extent (ha)	Vegetation extent (ha)
Natural						
Lakes						
Ox-Bow Lakes/	32	469.705 (2.64%)	164.741	294.339	165.079	307.963
Cut-Off Meanders	6	161.344 (0.91%)	57.891	92.749	56.656	182.223
Riverine Wetlands						
Waterlogged- Natural	2	37.429 (0.21%)	0.000	37.429	0.000	37.429
River/Stream	25	1103.614 (6.21%)	15.463	811.317	51.555	808.520
Total	24	13472.748 (75.77%)	4706.372	3812.140	5101.440	3117.531
Man-made	89	15244.841	4944.467	5047.974	5374.730	4453.666
Reservoirs/ Barrages	1	2330.584 (13.11%)	1626.963	154.935	2245.556	28.849
Waterlogged- Man made	9	205.931 (1.16%)	6.964	173.667	6.999	198.910
Total	10	2536.515	1633.927	328.602	2252.555	227.759
Grand Total	99	17781.355	6578.393	5376.576	7627.286	4681.425

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communication system and software. The research work listed above, demonstrates the advanced usage of geoinformatics for wetland development.

With the availability of higher resolution (spatial, spectral and temporal) digital satellite data, improvements in GIS, GPS, database, communication and hardware technology, the information content and the accuracy of the generated data can be considerably enhanced for natural resource management.

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Distribution of Trace Metals in Sediments from the Shelf Region of Karnataka, West Coast of India

Ulhas G. Naik, Shivakumar B. Haragi and U.G. Bhat

Department of Studies in Marine Biology, Karnatak University Post Graduate Centre, Kodibag, Karwar-581 303, Karnataka, India
E-mail: ugnaik66@yahoo.co.in

Abstract: The trace metals namely Fe, Al, Mn, Zn, Cu, Co, Ni, Cr and Mo of surficial sediment samples were collected at different depths from 25 stations located at three zones (in eight transacts) in the Arabian Sea during 208th cruise of RV Gaveshani during January 1989. It is summarized from the present study that the distribution of metals depends on the sediment texture in particular and the concentration of humic acids and organic matter in general. The role of riverine discharge and drainage could also significantly alter the concentration of metals in the marine sediments. It was observed that parameters like nature of the sediment, humic acids, organic matter etc., significantly influenced the distribution of metals in this region. Due to heavy mining activity and transportation of mines through sea route, there is likely to be high magnitude of leaching and variation of trace metals in this coast. Using this as benchmark data (1989), an attempt was made to compare the concentration of these metals with the present (2010) data to explain the concentration of these metals with space and time.

Key Words: Arabian Sea, Karnataka Shelf, Trace Metals, West Coast of India

Karnataka state has 310 km of coastline with five major riverine systems draining in to the Arabian Sea. These rivers seasonally discharge various terrigenous materials in to the sea, most of which ultimately deposits on the inner continental shelf and fish production is influenced by these discharge directly or indirectly. During IIOE period, (1961-65) several researchers have carried out geological investigation on western continental margin of India. Distribution of metals in the sediments of northern half of western continental shelf of India has been studied earlier (Murthy *et al.*, 1980; Manjunatha and Shankar, 1988; Shankar and Karbassi, 1991 and Nair, 2006). Determination of trace elements has received increasing attention in water pollution studies (Tucker, 1972). The potential toxic metal elements such as chromium, lead, zinc, iron etc are identified and caused health hazard in animals and plants (Bryan, 1976). In recent years, aquatic environments with trace metals have become serious environmental issues. Uptake of trace mental introduced anthropogenically in to the marine environment by sediments (Helz *et al.*, 1975) and its adverse effects on coastal waters are well recognized (Aston *et al.*, 1975; Bertine and Goldberg, 1971). Studies on the effect of trace metals on marine organisms and metals exchange with water, sediment system have suggested the use of sediment as indicator of metal pollution (Manjunatha and Shankar, 2001). Hence, an attempt has been made in the present investigation to study the distribution of some trace elements as base line data of coastal shelf of Karnataka during 1989 and 2010 period.

MATERIAL AND METHODS

A total of 25 sediment samples were collected from eight transects in the shelf region (Arabian Sea) perpendicular to the coast of Karnataka during the 208th cruise of RV Gaveshani (Figure 1), from January 10 - 20, 1989 using the Peterson grab. For trace metals analysis, about 10 g of uncontaminated sediment was collocated from the central portion of grab sample using a clean plastic spatula and then transferred into the polythene bag. The samples were washed with distilled water for removal of salts, air dried and finally powdered. Concentration of Fe, Al, Mn, Zn, Cu, Co, Ni, Cr and Mo were determined using AAS after digestion with a mixture of aqua regia. The size fraction analysis of sediment was carried out by pipette analysis (Loring and Rantala, 1977). An estimation of sediment organic matter and carbon was carried out as per method described by Day (1965).

RESULTS AND DISCUSSION

The results of the present study are categorized as trace metal distribution in sediment and other sedimentological parameters such as sand, silt and clay ratio, median diameter, organic matter and organic carbon. The entire study has been classified into three zones namely, inshore area, mid shelf area and shelf edge area for the purpose of interpreting the results.

Trace Metal

Distribution of trace metals in the shelf region off coastal Karnataka west coast of India during the present study period is portrayed in the Figure 2.

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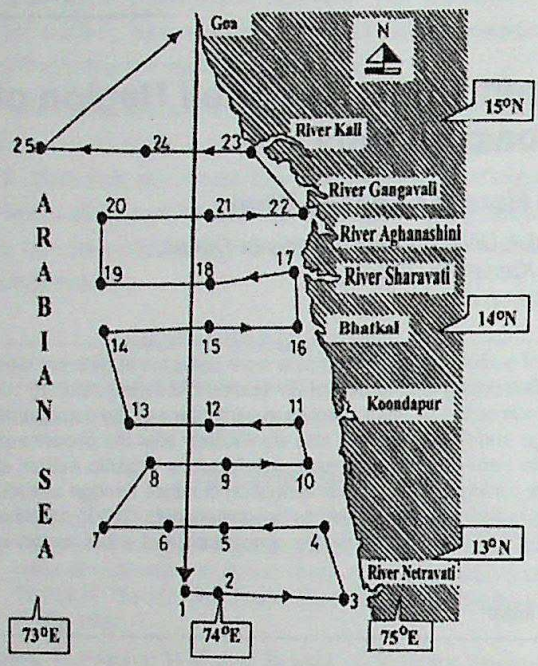


Fig 1. Cruise track of RV Gaveshani (Cruise No. 208) and location of study sites along the Karnataka coast

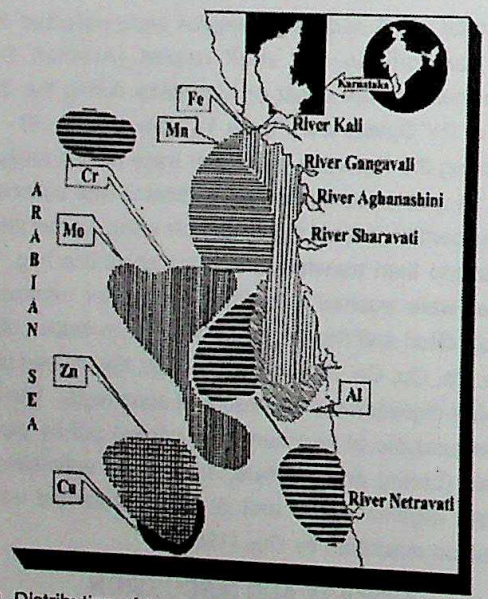


Fig 2. Distribution of traec metals in the shelf region off coastal Karnataka

Iron (Fe)

The minimum and maximum values of Iron were found at station 8 (0.01%) and at station 22 (2.8%), respectively. The average concentration of iron at three zones were 2.3%, 1.28% and 1.18% at inshore (shelf area) mid shelf and shelf edges respectively (Table 3). The concentration of iron ranged from 1.28 to 2.8% (average of 8 stations) in inshore area with the minimum concentration at station 4 and maximum at station 22 (Table 1). In mid shelf zone it ranged from 0.05% (stn.15) and 1.81 (stn.6) with average of 1.28% (Table 2). In the shelf edge zone, this metal varied between 0.01% (stn.8) and 2.14% (Stn. 25) and mean concentration of this zone was 1.18% (Table 3). Comparatively higher iron content (4.6%) was recorded at inshore waters of Karwar during the period 2010 (Fig. 3).

Aluminium (Al)

Aluminum concentration in sediment along the three zones ranged between 0.7% (Stn.19 & 15) and 7.6% in station 16. In the inshore region, the concentration of this metal varied between 2.04% (stn.22) and 7.6% (Stn.16) with mean concentration of 2.3% (Table 1). In mid shelf sediment, the concentration of this metal ranged between 0.7% (stan.15) and 2.3% (Stn.5) within an average concentration 1.55% (Table 2). At shelf edge region it varied between 0.7% (Stn. 19) and 3.5% (stn.25) with mean concentration of 2.42% (Table 3). In Karwar inshore waters, the content of aluminium was 7.38% (Fig 3) and was found to be higher compared to results obtained during 1989.

Manganese (Mn)

The concentration of Mn ranged between 36 ppm (Stn. 19) and 1840 ppm (Stn. 23) with a mean concentration of 212.08 ppm. In inshore region, its concentration varied between 58ppm (Stn. 4) and 1840 ppm (Stn. 23) with a mean of 361.25 ppm (Table 1). In mid-shelf sediments, its concentration varied from 80 ppm (Stn.15) and 404 ppm (Stn. 18) with a mean of 193.11ppm (Table 2). Compared to these two sectors, the lowest concentration of this metal was noticed at shelf edge region where it varied between 36ppm (stan.19) and 152ppm (Stn. 7) with a average of 84.25ppm (Table 3). It was relatively high (398.3ppm) at Karwar region during 2010 (Fig. 3).

Zinc (Zn)

The concentration of this element ranged from 3.4 ppm (stn.6) and 78.6 ppm (Stn. 8) with an average concentration of 28.72 ppm. Its concentration in the sediment of inshore region varied between 19.2 ppm (Stn. 4) and 42.8 ppm (Stn. 16) with a mean of 32.53ppm respectively (Table 1). In mid shelf sediment, its concentration varied between 9ppm (stn.15) and 78.6 ppm (Stn. 6) with a mean of 23.89 ppm (Table 2). Compared to these two zones, the concentration of this metal exhibited its value of 3.4 ppm (Stn. 8) and 76.8 ppm (Stn. 7) at shelf edge region where its average value was 30.35 ppm (Table 3). It was noticed that, concentration of zinc was 41.22 ppm but it did not show any drastic variation compared to earlier study (Fig 3).

Copper (Cu)

The average concentration of copper at 25 study sites was 13.97 ppm; however, the concentration of this metal varied from 2.6 ppm to 31.2 ppm (Stn. 8, 15, 18 and 6). In

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Table 1. Distribution of trace metals in the inshore sediments off Karnataka Coast

Station No.	Fe(%)	Al(%)	Mn (ppm)	Zn (ppm)	Cu(ppm)	Co(ppm)	Ni(ppm)	Cr(ppm)	Mo(ppm)
# 3	2.29	2.43	86	32.6	15	8.6	32.4	85	2.8
# 4	1.28	3.8	58	19.2	17.2	4	20	43.4	0.81
# 10	1.71	5.8	102	23	13.6	6.2	29.2	69.4	1.3
# 11	2.61	6	236	35.4	14.4	9.4	33.6	71.8	2.3
# 16	2.70	7.6	184	42.8	21.6	10.6	45.2	83.6	1.7
# 17	2.46	2.08	162	32.2	17	10	30.4	81.8	2.7
# 22	2.80	2.04	222	39.2	20.4	12	27.6	85	2.3
# 23	2.53	3.6	1840	35.8	20.4	10.2	37.4	84.2	1.7
Average	2.30	4.18	361.25	32.53	17.45	8.83	31.98	75.53	1.95

Table 2. Distribution of trace metals in the mid-shelf sediments off Karnataka Coast

Station No.	Fe(%)	Al(%)	Mn (ppm)	Zn (ppm)	Cu(ppm)	Co(ppm)	Ni(ppm)	Cr(ppm)	Mo(ppm)
# 2	1.73	1.76	98	36.8	20.6	8.4	42.4	58.2	3.9
# 5	1.43	2.3	216	19.4	11.6	8.6	43.4	68.4	6.6
# 6	1.81	1.7	102	78.6	31.2	10.8	66.4	83.6	3.4
# 9	1.36	1.36	180	11.6	5.2	4.8	16.2	42	1.8
# 12	1.3	1.37	220	12	6.4	5	14.4	42.2	2.1
# 15	0.05	0.7	80	9	2.6	6.2	13	39.6	4.1
# 18	0.67	0.78	404	9.2	2.6	3.6	12.4	24.2	2
# 21	1.49	1.8	282	19.8	9.6	9.2	36	50.8	2.6
# 24	1.66	2.16	156	18.6	7.2	8.6	29.5	83	2
Average	1.88	1.65	193.11	23.89	10.78	7.24	29.31	54.57	3.17

Table 3. Distribution of trace metals in the shelf-edge sediments off Karnataka Coast

Station No.	Fe(%)	Al(%)	Mn (ppm)	Zn (ppm)	Cu(ppm)	Co(ppm)	Ni(ppm)	Cr(ppm)	Mo(ppm)
# 1	1.75	3.4	112	69.6	27.6	8.6	43.4	45	1.7
# 7	2.05	2.26	152	76.8	29.6	10	59.6	46.6	3.4
# 8	0.01	1.1	84	3.4	2.6	6.6	13	24.2	2
# 13	0.84	2.6	106	9.2	5.4	4	18	33.6	2
# 14	0.89	2.6	68	20.6	11.6	8	33	55.2	5.4
# 19	0.6	0.7	36	12.8	6.4	4.8	2	35.4	2.9
# 20	1.14	3.2	58	13	11.8	10.4	30.2	35.2	4.7
# 25	2.14	3.5	58	37.4	17.6	10	44.2	83.6	3.9
Average	1.18	2.42	84.25	30.35	14.08	7.8	30.43	44.85	3.25

the inshore region, its concentration varied between 13.6 ppm (Stn.10) and 21.6 ppm (Stn. 16) with mean of 17.45 ppm (Table 1). In mid shelf region, its concentration varied between 2.6 ppm and 31.2 ppm (Stn. 15, 18 & 6) (Table 2) with an average of 10.78 ppm. Average concentration of this metal at shelf edge was 14.08 ppm with a minimum of 2.6 ppm (Stn. 8) and maximum of 29.6 ppm (Stn. 6) (Table 3). In Karwar region, it showed concentration of 24.51 ppm during 2010 period (Fig 3).

Cobalt (Co)

An average concentration of cobalt at 25 study station was 7.94 ppm and it ranged between 3.6 ppm and 12 ppm (Stn. 18 & 22). In inshore areas, its concentration varied from 4 and 12 ppm, (Stn. 4 and 22) while mean concentration was 8.83 ppm (Table 1). In mid shelf the average concentration was 7.24 ppm while minimum and maximum was noticed at station 18 (3.6 ppm) and station 6 (10.8 ppm) (Table 2). In the shelf edge station, its concentration varied from 4 to10.4 ppm (Table 3) with an average of 7.8 ppm. An average concentration of this metal at three sectors was in order of 8.83, 7.80 and 7.24 ppm respectively. Concentration of this metal was 18.7 ppm which was comparatively higher than the earlier data recorded (Fig. 3).

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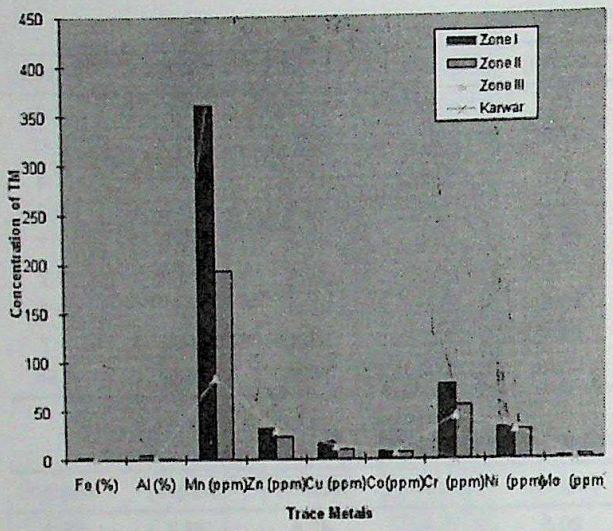


Fig 3. Distribution of trae metals in the shelf regon off coastal Karnataka

Nickel (Ni)

The average nickel concentration at three sectors was 30.52 ppm and its concentration varied between 2.0 (Stn.19) and 66.4 ppm (Stn. 6). Mean concentration of this metal along the inshore area was 31.98 ppm and here its concentration varied between 30 and 45.2 ppm (Stn. 4 & 6) (Table1). In mid shelf, it varied between 12.4 and 66.4 ppm at 18th and 6th station (Table 2), respectively. In the shelf edge area, metal concentration varied between 2 (Stn. 19) and 59.6 ppm (Stn. 7) with a mean concentration 30.43 ppm. Concentration of nickel at three sectors were in order of 31.98 (near shore shelf area), 30.43 ppm (mid shelf area) and 29.31 ppm (shelf edge area) respectively. The nickel concentration was observed 81.1 ppm in Karwar waters which was relatively higher than earlier observation (Fig 3).

Chromium (Cr)

The chromium concentration ranged between 24.2 and 85 ppm at study area with an average of 58.2 ppm. The inshore shelf area exhibited a low concentration of 43.4 ppm (Stn. 4) and 85 ppm (Stn. 3 and 22) (Table 1). In mid shelf area, it was in the range of 24.2 ppm and 83.6 ppm at station 18 and 6 with an average of 54.67 ppm (Table 2). A similar pattern was noticed in shelf edge area with an average chromium concentration in sediments at three sectors in the order of 75.53, 54.67 and 44.85 ppm.

Molybdenum (Mo)

Minimum and maximum concentration of Molybdenum was 0.81 and 6.6ppm with average concentration of 2.8ppm in the study area, respectively. In inshore region, it varied between 0.81 and 2.8ppm with an average of 1.95ppm (Table 1). The mid shelf and shelf zone had exhibited slightly higher concentration of trace metals with an average of 3.17 and 3.25ppm (Table 2 and 3).

Organic Carbon (OC)

The results of organic carbon in sediments are shown in Table 4. The concentration of organic carbon in the inshore shelf area varied between 1.55 and 2.94% with a average of 2.32% while in mid shelf sediment OC ranged from 0.12 to 4.10%. Similarly, in shelf edge area, it was between 0.15 and 2.35%. In inshore, mid shelf and shelf edge area its average values were 2.32, 0.95 and 1.39%, respectively.

Organic Matter (OM)

Among the three sectors, the minimum values (average) was noticed as 1.64% in mid shelf and 2.4% in the shelf edge area (Table 4).

Sand, Silt and Clay ratio

Average values of Sand, silt and clay along the 8 transact of 25 stations were 82.12, 11.66 and 6.34%, respectively (Table 4). In the inshore area average amount of sand, silt and clay were 17.18, 15.21 and 6.11%, in mid shelf zone the mean of sand, silt and clay were of 87.84, 6.83 and 5.32% and in the shelf edge area the values of these three components were in the order of 76.37, 14.12 and 19.51% (Figure 3).

In the present study, the concentration of iron ranged between 0.01-2.29%. In general the lower values have been encountered in the shelf-edge zone while the inshore sediments have shown higher values of iron. In sector wise variation, the inshore sediments have shown relatively higher concentration of iron except for the two stations (# 4 & 10) where there is no riverine discharge. Here the concentration was more than average concentration of 25 stations. In the present study, a high significant correlation was observed between iron and organic matter ($r=0.659$; $P=< 0.001$; Table 5). This is in agreement with earlier observations (Karbassi and Shankar, 2005). There was no significant relationship observed between iron and clay ($r=0.183$) and this is in contrast to the earlier observations (Bryan, 1976). Comparatively higher iron content was observed in the present study. This suggests that the iron content in these clay sediments is mostly bound with organic matter while a very little fraction is found to be associated with silt fraction of the sediment. High positive correlation of metals with organic matter and fine grained fraction of the sediments can be attributed to the very small size of autogenic sulphides. The sulphide production in turn is dependent on the amount of decomposable organic matter.

Though it is very abundant element next to iron in the earth's crust because of its mineral alumina and aluminosilicates it is rarely known to interact with other inorganic and organic fractions (Goldberg and Arrhenius 1958). Hence, its bioavailability is not pronounced as compared to other metals. There are no reports of

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aluminium toxicity to the biota. The average aluminium concentration in the continental crust is 8.23% (Taylor *et al.*, 1983). In the present study, the distribution of aluminium exhibits a decreasing trend away from the coast but suddenly increases in the shelf edge zone. In inshore zone the concentration was very high at stations 10, 11 and 16 and abruptly decreased in the other inshore stations. This decrease in concentration is due to the riverine discharge and the sediment texture of these stations is mostly sandy. The higher concentrations are associated with the mud of inshore zone. Geochemically, since the aluminium is located mainly in the aluminosilicates and it has been used as index for the inorganic and argillaceous fractions of the sediments (Goldberg and Arrhenius, 1958). The distribution of aluminium in marine sediments is almost exclusively controlled by the input of detrial aluminosilicates to the oceans from the continents. Quantitatively clay minerals and feldspars are the major sources for aluminium in marine sediments, although it occurs to a lesser degree in many other minerals of the inshore sediments. Studies on chemical extractions of sediments indicative that aluminium largely located in the clay minerals where it is held in crystals lattices. The concentration of aluminium in these sediments is higher than many other inshore sediment but is well below the average aluminium contents of terigenous clay (17.2%) as reported earlier (Clarke, 1924). Relatively low values of aluminium in these sediments may be attributed to the occurrence of the montmorillonite a mineral with low aluminium ratio and to a smaller extent substituent of aluminium by Fe^{+3} and Fe^{+2}, in the octahedral positions.

There was no significant correlations of aluminium with humic acid and clay (r=0.150 and 0.20) but it showed a significant positive correlations with organic matter and silt (r=0.148 and 0.318. P= 0.05, d.f. 23) (Table 5). This indicates that the aluminium concentration in these sediments may be associated with organic matter other than humic acids.

Manganese

The maximum concentration of manganese (1840 ppm) was noticed at the mouth of river Kali while the minimum being 36ppm of Sharavati. The inshore zone had high average of this metal than other two zones. The shelf zone had less concentration of manganese than inshore zone; this is due to the fine grained sediment of inshore and mid-shelf zones. In the near and mid-shelf zone the

Table 4. Sedimentological parameters at different study sites located along the shelf region off coastal Karnataka

Station No.	Sand (%)	Silt (%)	Clay (%)	Organic Matter (%)	Organic Carbon (%)
#1	40.3	35.3	24.4	4.05	2.35
# 2	74.0	14.6	11.4	3.64	2.11
# 3	76.8	19.1	4.10	5.1	2.94
# 4	77.2	11.0	11.8	2.66	1.55
# 5	92.0	4.9	3.1	1.13	0.65
# 6	52.9	29.2	17.9	7.07	4.1
# 7	31.0	41.0	28.0	3.43	2.0
# 8	97.4	1.3	1.3	0.36	0.15
# 9	90.1	1.70	8.2	0.2	0.12
# 10	82.3	17.2	0.5	4.55	2.67
# 11	78.0	17.9	4.1	3.23	1.87
# 12	97.4	2.6	0.0	0.31	0.18
# 13	95.6	0	4.4	1.08	0.62
# 14	69.6	21.5	8.9	2.87	1.66
# 15	98.4	0.60	1.0	0.31	0.18
# 16	79.7	15.7	4.6	4.2	2.44
# 17	84.2	14.2	1.6	3.53	2.05
# 18	97.0	1.60	1.4	0.31	0.18
# 19	92.5	4.4	3.1	2.61	1.52
#20	94.4	3.7	1.9	2.15	1.25
# 21	92.5	4.7	2.8	0.85	0.50
# 22	83.2	12.7	4.1	4.56	2.64
# 23	82.2	13.9	3.7	4.15	2.41
# 24	96.4	1.6	2.0	0.92	0.54
# 25	90.1	5.8	4.1	2.71	1.57
Average	82.12	11.66	6.34	2.64	1.53

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manganese content is influenced more by the lithogenous component. The manganese content of deep sea deposits has been attributed to different agencies – volcanic eruptions, submarine weathering (Murray and James,1924), bacterial precipitations, biological extractions, chemical precipitations (Karbassi,1996). In the shelf zone concentration of manganese is due to weathering of land mass. Manganese is carried to the sea as a constituent of sedimentary debris (Karbassi and Shankar, 2005) and associated with fine grained clay minerals. In the present study high manganese content in the inshore and midshelf sediments observed which indicates larger input of this metal from the nearby land mass thorough lithogenous supply and its retention in the finer fraction of the sediment in the oxidizing environment concluded that most of the manganese in the sediment was derived from the weathering of rocks in the drainage basins of the local rivers. In the present study there was no significant correlation observed between manganese, organic matter, humic acids, silts and clay.

Zinc

The zinc concentration was found to vary with sediment texture and location. In the present study zinc showed significant positive correlation with organic matter, humic acid, silt and clay (r values in the order of 0.762, 0.5799. 0.899 and 0.797) which were significant at 5% level (Table 5). This agrees with the previous works (Mantoura *et al.*, 1978; Mahalingam, 2004).

Copper

The average copper concentration in the continental crust is reported to be about 55ppm (Karibassi and Shankar, 2005). The average copper content of the sediment in the present study area is comparable to that of the northern Arabian Sea shelf sediments of the east coast of India but lower than that of Kakinada-Pentakota shelf sediments and deep sea clays. Copper holds a strong positive relationship with aluminium, iron, and manganese while shelf edge sediments show the relationship with the metals like manganese, iron and aluminium (Rao *et al.*, 1974). Copper showed a highly significant positive relationship with organic matter, humic acids, silt and clay at 25 study stations (r=0.837, 0.646, 0.865, 0.731 in the same order) which were significant at 1% level (Table 5). This indicates copper is bound to both organic and inorganic ligands in our waters. Generally high levels of copper concentration are noticed in near shore and deep water sediments than the surface waters. This suggests that copper is easily bound by particulate organic matter. Copper is sorbed rapidly onto sediments, resulting in high residue levels. Rate of sorption varies with the typs of clay, sediment, pH, competing cation and presence of ligands and Fe/Mn oxides.

Cobalt

Cobalt is mainly associated with clay minerals like iolite (Chester, 1965). It has affinity towards both organic and inorganic ligands in the sea water. Cobalt is very essential element for invertebrates where the cobalt is associated with cyanocobalamin (i.e., Vitamin B_{12}) synthesis in most of the invertebrates, especially mollusks. The invertebrates use cobalt in enzyme synthesis. Cobalt is known to be introduced into the marine environment in solution and as part of or in association with solid organic and inorganic particles supplied from natural sources (Chester and Hughes, 1965). Cobalt concentration found in the sediments of the present study area and those found elsewhere indicate that cobalt concentrations in the sediments here are slightly higher than the open Gulf of the St. Lawrence and inshore sediments. They are far below the reported average value of the Indian east coast shelf clays and deep sea clays. In the present study, cobalt showed a significant relationship with organic matter (r=0.588 at 1% level) and is also showed significant relationship with silt (r=0.471) significant at 5% level (Table 5).

Nickel

Nickel is known to be responsible for redox potential of sediments along with Fe, Mn and Co. It is abundant in earth's crust as oxides, carbonates, silicates with Fe, Mg and as sulphides, arsenides and tellurides. Variations of Nickel with organic matter, humic acids, silt and clay are shown in the Table 5. The average Nickel concentration in the continental crust is reported to be about 125ppm (Karbassi and Shankar, 2005). The maximum concentration of this metal was observed in the mid shelf zone (Table 4),

Table 5. Correlation matrix between different sedimentological parameters and trace metals

	Om	HA	Silt	Clay	Fe	Al	Mn	Zn	Cu	Co	Ni	Cr	Mo
OM	1.0	0.663**	0.727**	0.420*	0.659**	0.428*	0.096	0.762**	0.837**	0.588**	0.671**	0.645**	0.051
HA	0.663**	1.0	0.481*	0.510**	0.414*	0.15	0.149	0.579**	0.646**	0.270*	0.508**	0.380*	0.071
Silt	0.727**	0.481*	1.0	0.830**	0.477*	0.318*	0.007	0.899**	0.865**	0.471*	0.745**	0.457*	0.006
Clay	0.420*	0.510**	0.830**	1.0	0.183	0.02	0.13	0.797**	0.731**	0.209	0.623**	0.144	0.015

* Significant at 5% level; ** Significant at 1% level; Om = Organic matter; HA = Humic acid

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the reason for this could be due to fine grained sediment. The mean concentration of nickel in this zone was less than the average of 25 stations. The lowest concentration of nickel was noticed at station 19 which falls in the shelf edge zone. Here the sediment was containing more sand. Beside the terrigenous source some other sources also control the distribution of Nickel in these sediments. A high Ni/Al ratio for the slope sediments off Mumbai was observed (Borole *et al.*, 1982). Large fraction of nickel is removed in the marine environment by the scavenging action of Fe and Mn oxides and hydroxides (Gupta and Chen,1975). The contents of Cu, Ni and Zn correlated well with organic matter in the marine sediments as described earlier (Clevert and Price, 1970). Nickel is enriched in marine organism relative to sea water to a greater extent than many of the other trace elements (Hogdahl, 1963). In the present study there was a high significant relationship with organic matter, humic acid, silt and clay. It showed high significant values at 1% level (r= 0.671, 0.508, 0.745, 0.623 in the same order) and this agreed with the earlier studies (Clevert and Price, 1970).

Chromium

Chromium in the inshore zone showed higher concentration, however there was a decrease in concentration of chromium away from the coast in both the zones (mid shelf and shelf –edge zones). This shows that the sediment grain size has a greater effect on the distribution of this metal. The mid shelf zone had high concentration of chromium (Stn. 6) which had less sand percent and more clay percent. On the other hand the shelf edge zone had more concentration of chromium off Karwar (Stn. 22, 23, 24 and 25), higher values of chromium noticed was 80 ppm. This can be attributed to the riverine (Kali) influence on this metal. The chromium showed a highly positive significant correlation with organic matter (r=0.645, P 0.05). However, no significant relationship was observed with clay fraction of the sediments (r=0.144) as shown in the Table 5.

Molybdenum

In the present study it was observed that the concentration of molybdenum increased from the inshore to the shelf zone. The inshore zone was showing less concentration of this element with an average of 1.95ppm. In mid shelf zone an uniform distribution of this trace element was observed compared to other zones, the maximum concentration of this element was noticed all along this zone. But comparatively high concentration of this element was observed in the shelf-edge zone than other zones and the reason for high values can be due to the sediment grain size wherever the percent of sand was more and this is related in the negative correlation values with organic matter, humic acids, silt and clay (Table 5).

Studies on organic matter in sea floor sediments are important from the following two points (i) organic matter, especially of marine origin is believed to be the source material for petroleum, and (ii) it plays significant role in geochemical cycles of major and trace metals that accumulates in sediments. The content of organic matter in the study stations ranged from 0.2 to 7.07% (average 2.64%) highest organic matter content was noticed off Mangalore and the lowest at the station 9. Regionally the shelf of north Karwar contains more organic matter. Silty-clay and clayey-silt type sediments are richer in organic matter content than sand and silty sand. The organic matter showed a highly significant relationship with humic acid and silt (r=0.663, 0.727, P< 0.001), but only significant relationship established with clay fraction (r=0.42, P<0.05) as shown in Table 5.

An average sand, silt and clay percent at 25 stations off Karnataka coast was 82.12, 11.65 and 6.34% (Table 4). Along the inshore zone average sand and clay content were less and the silt fraction was more, hence, the metals and organic matter were generally more. An average of sand, silt and clay percent along the inshore zone was more (87.84%) than the silt (6.83%) and clay (5.32%) fraction and the metals also showed an inverse trend along this zone. This zone showed a good relationship of high concentration of metals with respect to the good relationship of high concentration of metals with respect to the fine grain fractions.

It is summarized from the present study that, the distribution of metals depends on the sediment texture in particular and the concentration of humic acids and organic matter in general. Besides this, the role of riverine discharge and land drainage could also significantly alter the concentration of metals in the marine sediments. The results obtained from the present study thrown some light on parameters such as sediment nature, humic acids, organic matter etc as they significantly influenced the distribution of metals in this region. In order to ascertain the role of these parameters and to develop a time series distribution of these trace metals in coastal waters of Karnataka, an intensive study should be carried out over a longer period of time.

Summarization of three zones indicated that the iron, aluminium, manganese and cobalt was comparatively higher in the inshore water (zone-I: 2.3%, 4.18% and 361.25

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& 8.83ppm respectively. On the contrary, the present data reveals that there is marked increase in the concentration of these metals in the inshore waters of Karwar coast i.e. iron (4.6%), Aluminium (7.38%), manganese (398.3ppm) and cobalt (18.7ppm) during 2010 period. The observed increased trend in iron, manganese is probably due to heavy mines transportation through sea route which might have been caused by leaching from the dumping sites in offshore area. However, increased concentration of aluminium and cobalt and organic matter content is due to the high sedimentation rate and their proximity to river mouth. According to Karbassi and Shankar (2005) that copper, zinc, iron are associated with the organic matter and detrital particle whereas nickel and cobalt are predominantly associated with insoluble fraction.

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Production Potential and Quality of Coarse Rice (*Oryza sativa* L.) as Influenced by Hybrids and Dates of Direct Seeding and Transplanting

Thakar Singh, C.S. Aulakh, R. Sikka, Kulbir Singh, P.P.S. Pannu and Savita Sharma*****

Department of Agronomy, Plant Pathology** and Food Science and Technology***
Punjab Agricultural University, Ludhiana-141004, Punjab, India
E-mail:thakar1962@yahoo.com

Abstract: A field experiment was conducted during *kharif* 2011 at Punjab Agricultural University, Ludhiana to study the effect of different dates of direct seeding and transplanting on yield and quality of hybrid rice. It was laid out in a split-plot design with two hybrids (SVH 5 and SVH 26) along with a cultivar (PR115) in main plots and four dates of direct seeding (1 June, 15 June, 30 June and 15 July) and four dates of transplanting (21 June, 6 July, 21 July and 5 August) in sub-plots. Maximum mean grain yield (50.0 q/ha) was recorded in hybrid SVH 26 which was followed by SVH 5 (49.0 q/ha) and PR 115 (46.9 q/ha), however, the differences in grain yield were non-significant. Crop transplanted on 21 June and 6 July recorded significantly higher grain yields of 62.5 and 61.2 q ha^{-1}, respectively, whereas, among direct seeding dates highest grain yield of 49.0 q ha^{-1} was recorded in 1 June sown crop that was at par with 15 June direct seeded crop. Highest 1000-grain weight (22.6 g) and grains per panicle (179.9) were recorded in 21 June transplanted crop followed by 6 July transplanted crop while in direct seeded crop, 1 June sown crop had highest 1000-grain weight of 21.9 g. Transplanted crop recorded significantly higher head rice recovery (59.1 to 62.1 %) as compared to direct seeded crop (55.7 to 56.6 %). Lowest minimum cooking time of 11.2 minutes was taken by the grains from 1 June direct seeded crop that was statistically at par with 15 June direct seeded crop. A significantly higher water absorption ratio of 3.4 was recorded in grains obtained from crop direct seeded on 1 and 15 June as well as crop transplanted on 21 June and 6 July. Crop transplanted on 21 June recorded a maximum B: C ratio of 2.3 that was statistically at par with crop transplanted on 6 July as well as 1 and 15 June direct seeded crop. It can be concluded that hybrid rice crop should be raised through transplanting from 21 June to 6 July and through direct seeding from 1 June to 15 June for getting higher productivity, good grain quality and better returns.

Key words: Direct seeded rice, transplanted rice, hybrid rice, grain yield, quality.

Hybrid rice is likely to play an important role in improving world food security. The grain yield of existing high-yielding varieties of rice has almost reached the potential level in irrigated rice systems forcing the policy makers to consider development and use of hybrid rice technology (Janaiah, 2002). During the last ten years, growth in rice yield has remained below 1 %, whereas, to meet food demands of growing population we need an average increase of over 1 % every year (Normile, 2008). So far, Indian farmers have shown reluctance to accept hybrid rice which may be attributed to difficulty in seed availability as well as higher seed costs. However, during recent years there has been significant improvement in hybrid rice technology. The yield potential of hybrid rice has been reported to be 9% more as compared to inbreds (Peng *et al.*, 1999). In Karnataka, hybrids KHR 1 and KHR 2 proved to be superior in terms of yield over popular inbred varieties *Mangla* and *Jaya*, respectively, to the tune of over 1 t ha^{-1} (Rudraradhya *et al.*, 1998).

Presently, forced by the prevailing ecological as well as economic considerations, the research workers as well as growers are looking at direct seeding (DS) crop establishment method of rice as a substitute to transplanted rice. In many tropical Asian countries the adoption of DS may be attributed to higher transplanting charges as well as labour shortage. In other regions, the shift towards direct seeding has been primarily due to depleting water tables. Increase in seed yield to the tune of 3-17 %, 19 % less water requirement during crop growth period and 25-48 % increase in water productivity was recorded when rice was grown by direct seeding method as compared to traditional transplanting (Tabbal *et al.*, 2002). Irrespective of the method of establishment, proper date of planting is important particularly for optimum yields as once yield reductions occur due to improper time of sowing or transplanting nothing could compensate. Aslam *et al.* (2001) reported that crop sown during third week of June gave significantly higher grain yield over crop sown during first week of June and first week of July.

From the aforementioned facts, it is quite clear that hybrids can play an important role in raising the ceiling for yields in rice and the performance varies from hybrid to hybrid and planting time. Keeping all these points in mind the field experiment was conducted to study the effect of dates of direct seeding and transplanting on yield and quality of hybrid rice under Punjab conditions.

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MATERIAL AND METHODS

The present study was carried out at Research farm, Department of Agronomy, PAU, Ludhiana during *kharif* 2011. The soil of the field was sandy loam in texture with pH 7.5, 0.38 % organic carbon and low in available N (116.2 kg ha^{-1}), high in available P (36.4 kg ha^{-1}) and medium in available K (291.2 kg ha^{-1}). The experiment was laid out in a split-plot design with two hybrids (SVH 5 and SVH 26) along with a variety (PR 115) in main plots and four dates of direct seeding (1 June, 15 June, 30 June and 15 July) and four transplanting dates (21 June, 6 July, 21 July and 5 August) in sub-plots with three replications. For direct seeded crop 20 kg ha^{-1} seed was used, whereas, for transplanted crop 21 days old seedlings were used raised with the same seed rate. Phosphorus and potash both at 30 kg ha^{-1} were applied at sowing or before last puddling depending upon method of establishment. Nitrogen at 150 kg ha^{-1} was applied in four equal splits at two, four, seven and ten weeks after sowing in direct seeding, whereas, in transplanted crop nitrogen at 125 kg ha^{-1} was applied with 1/3 before last puddling and the remaining in two equal splits, one three weeks after transplanting and other three weeks thereafter. In direct seeded crop for weed control pendimethalin at 750 g ha^{-1} was applied as pre-emergence followed by bispyribac at 100 g ha^{-1} at 30-35 DAS by mixing them in 375 litres of water. In transplanted crop for weed control butachlor at 1.5 kg ha^{-1} was applied two days after transplanting. To overcome iron deficiency, foliar spray of ferrous sulphate (1%) was done. Irrigations and plant protection measures were applied as per recommendation. The crop was harvested depending upon the date of maturity and yield attributing characters and grain yield were recorded. For milling percentage, 100 g paddy samples were de-hulled using a shelling machine to obtain brown rice. This brown rice recovered was further subjected to polishing to obtain polished rice. This polished rice was further passed over head rice grading machine to determine head rice obtained on paddy basis. L-B ratio raw and L-B ratio cooked were calculated using average length and breadth of ten grains each for raw as well as cooked rice. Minimum cooking time (MCT) was determined by taking two gram of head rice sample in test tube with 20 ml distilled water and cooked in boiling water bath and pressing few kernels taken from sample at different times between two glass plates till no translucent core was left. Water absorption ratio (WAR) and Kernel elongation ratio (KER) were calculated using the formulae:

$$WAR = W_C / W_R,$$
$$KER = L_C / L_R$$

Where,

W_C = Weight of cooked grains,

W_R = Weight of raw grains,

L_C = Length of cooked grains

L_R = Length of raw grains

Amylose content and aroma were determined using methods as proposed by Graham, (2002).

RESULTS AND DISCUSSION

Effect on Crop Growth

Plant height recorded at harvest did not differ significantly among hybrids and variety. However, date of seeding and times of planting caused significant influence on plant height (Table 1). Maximum plant height (103.8 cm) was recorded in 21 June transplanted crop that was statistically at par with plant height recorded in crop transplanted on 6 July but was significantly higher than that recorded in crops direct seeded or transplanted on all other dates. Similarly, decrease in plant height with delay in date of sowing was reported by Bashir *et al.* (2010).

Number of tillers m^{-2} at harvest was also non-significantly influenced by variety and hybrids. Maximum number of tillers (295 m^{-2}) was recorded in hybrid SVH 26. Dates of direct sowing and transplanting significantly influenced number of tillers m^{-2} at harvest. The maximum number of 331 tillers m^{-2} was recorded in direct sowing on 1 June which was at par with that recorded in crop direct sown on 15 June but significantly higher than all other direct seeding and transplanting dates. Among transplanting dates, crop transplanted on 21 June produced maximum number of tillers (297 m^{-2}) that were statistically at par with number of tillers recorded in 6 July transplanted crop but were more than both other transplanting dates. Lowest number of tillers (262 m^{-2}) was produced in 5 August transplanted crop. This decrease in number of tillers with delay in sowing or transplanting might be due to shortening of crop growth period.

Days taken to panicle emergence were significantly influenced by both the factors. On an average, Hybrid SVH 26 took minimum number of 81 days to panicle emergence that were statistically at par with days taken to panicle emergence by SVH 5 hybrid but were significantly lower than days taken to panicle emergence by variety PR 115. Among different dates of direct seeding and transplanting, minimum of 81 days were taken to panicle emergence by direct sowing on 15 July which were statistically at par with days taken to panicle emergence by crops transplanted on 6 July, 21 July and 5 August but were significantly lower than all other dates.

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Table 1. Growth, yield attributes and grain yield of rice as influenced by hybrids and date of direct seeding and transplanting

Treatment	Plant height (cm)	Tillers m^2	Days to panicle emergence	Panicle length (cm)	Branches $Panicle^{-1}$	Grains $panicle^{-1}$	1000-grain weight (g)	Grain yield (q ha^{-1})
Hybrid/Variety								
Hybrid SVH 5	86.8	294	83	24.3	11	157	21.4	49.0
Hybrid SVH 26	94.2	295	81	25.8	11	160	21.8	50.0
Variety PR 115	87.3	285	88	25.3	11	155	21.3	46.9
CD (p=0.05)	NS	NS	3	NS	NS	NS	NS	NS
Date of direct seeding and transplanting								
1 June (direct seeded)	96.2	331	88	25.9	11	165	21.9	49.0
15 June (direct seeded)	91.6	323	85	25.5	11	164	21.4	48.2
30 June (direct seeded)	82.4	289	84	25.1	11	148	21.1	43.4
15 July (direct seeded)	71.5	266	81	23.3	11	137	20.3	34.0
21 June (transplanted)	103.8	297	86	27.0	12	180	22.6	62.5
6 July (transplanted)	100.4	289	82	26.2	12	178	22.4	61.2
21 July (transplanted)	89.7	275	82	24.8	11	149	21.8	48.9
5 Aug (transplanted)	79.8	262	82	23.7	11	140	20.6	41.8
CD (p=0.05)	4.8	19	2	1.4	NS	11	1.0	5.2

All interactions: NS

Effect on Yield Attributes and Grain Yield

Panicle length did not differ significantly among hybrids and variety. Dates of direct seeding and transplanting caused significant influence on the panicle length. The maximum panicle length of 27.0 cm was recorded in crop transplanted on 21 June and it was statistically at par with panicle length recorded in crop transplanted on 6 July and direct sown on 1 June but significantly more than panicle length recorded in crop direct seeded and transplanted on remaining dates. Number of branches per panicle was not significantly influenced by varieties as well as dates of direct sowing and transplanting.

Number of grains per panicle were not-significantly influenced by hybrids and variety. Highest mean number of grains per panicle (160) were recorded in hybrid SVH 26. Dates of sowing and transplanting influenced this attribute significantly. Maximum number of grains per panicle were recorded in 21 June transplanted crop followed by 6 July transplanted crop which were significantly higher to that recorded in all dates of sowing and 21 July and 5 August transplanted crop.

Thousand grain weight was non-significantly influenced by hybrids and variety, whereas, dates of direct seeding and transplanting influenced 1000-grain weight significantly. The highest 1000 grain weight of 22.6 g was recorded in crop transplanted on 21 June that was significantly higher than that obtained in crop direct seeded on 15 June, 30 June, 15 July and transplanted on 5 August but was statistically at par with all other dates.

Hybrids and variety remained statistically at par with respect to grain yield. However maximum grain yield (50.0 q ha^{-1}) was obtained in hybrid SVH 26 followed by hybrid SVH 5 (49.0 q ha^{-1}) and variety PR 115 (46.9 q ha^{-1}). Among date of direct seeding and transplanting, the highest mean grain yield (62.5 q ha^{-1}) was obtained by transplanting rice on 21 June, which was statistically at par with grain yield obtained by transplanting on 6 July and significantly higher than yield obtained in all other treatments. Higher grain yield in 21 June and 6 July may be due to higher number of grains per panicle and 1000 grain weight in crop transplanted on these dates. Among the direct seeding treatments, the crop sown on 1 June produced maximum and significantly higher mean grain yield (49.0 q ha^{-1}) of rice as compared to direct seeding on 30 June and 15 July but was statistically at par with grain yield obtained in crop direct seeded on 15 June. These results are in line with findings of Abou khalifa, (2009) in direct seeded and Baloch *et al.* (2006) in transplanted rice who reported higher values of yield attributes and grain yield in earlier sown/transplanted crops with continuous decline with delay in sowing or transplanting.

Effect on Rice Quality

On an average, hybrid SVH 5 recorded highest brown rice recovery (BRR) of 82.9 % and it was significantly better than hybrid SVH 26 (81.5 %) and variety PR 115 (81.4 %). Among various dates of direct seeding and transplanting, the maximum BRR of 82.6 % was recorded in crop transplanted on 6 July that was statistically at par with BRR

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in crop transplanted on 21 June and 21 July but was significantly higher than all other dates for both direct seeded as well as transplanted crops (Table 2). Maximum polished rice recovery (PRR) of 73.7 % was recorded in hybrid SVH 5 and it was significantly higher than PRR in hybrid SVH 26 (70.1 %) and variety PR 115 (71.5 %). The highest PRR (73.3%) was recorded in crop transplanted on 21 June that was statistically at par with PRR in crop transplanted on 6 July but was significantly higher than all other dates for both direct seeded as well as transplanted crop. Head rice recovery (HRR) was not significantly influenced by hybrids and variety and it varied from 57.4 to 59.9 %. Dates of direct seeding and transplanting influenced HRR significantly with the highest value of 62.1 % recorded for crop transplanted on 6 July that was statistically at par with HRR in all transplanted dates but was significantly better than HRR of 55.7-56.6% obtained in all direct seeded dates. In general, for all the dates, BRR, PRR as well as HRR were higher in transplanted rice as compared to direct seeded. Chen *et al.* (2011) also recorded higher brown and head rice percentages in transplanted crop than in direct seeded.

Minimum time for cooking (11.5 minutes) was taken by hybrid SVH 5 that was statistically at par with time taken for cooking by variety PR115 but significantly lower than minimum time for cooking recorded in hybrid SVH 26. In different dates of sowing and transplanting, minimum duration for cooking increased continuously with delay in sowing or transplanting and was influenced significantly. Minimum time for cooking of 11.2 minutes was recorded in crop direct seeded on 1 June that was statistically at par with minimum time for cooking taken by grains of crop direct seeded on 15 June but was significantly lower than minimum time for cooking recorded in crops sown and transplanted on all other dates.

WAR was influenced non-significantly by hybrids but dates of direct sowing and transplanting influenced WAR significantly. Crops direct seeded on 1 June and 15 July and transplanted on 21 June and 6 July recorded highest WAR. Kernel E R, L/B ratio raw and L/B ratio cooked rice were not significantly influenced by hybrids as well as dates of direct seeding and transplanting.

The maximum mean amylose content was recorded in variety PR 115 (14.2 %) followed by SVH 26 (14.1 %), whereas, least amylose content was recorded in SVH 5 (12.2 %). In various dates of sowing and transplanting, amylose content increased continuously with delay in sowing or transplanting that might be due to continuous decrease in temperature at grain filling stage. Sano *et al.* (1985) also reported increase in rice endosperm amylose content with lowering of temperature during grain filling. The maximum amylose content was recorded in crop direct sown on 15 July.

Highest mean aroma score of 1.6 was recorded in SVH 26 followed by SVH 5 (1.5), whereas, least aroma score in variety PR 115 (0.4 %). In different dates of sowing and transplanting, aroma score was, in general, higher in direct seeded crops as compared to transplanted ones. Highest

Table 2. Rice quality as influenced by hybrids and date of sowing or transplanting

Treatment	Brown rice (%)	Polished rice (%)	Head rice (%)	MCT (minutes)	WAR	KER	L-B ratio raw	L-B ratio cooked	Amylose content (%)	Aroma (score)
Hybrid/Variety										
Hybrid SVH 5	82.9	73.7	58.0	11.5	3.3	1.41	3.32	3.91	12.2	1.5
Hybrid SVH 26	81.5	70.1	59.9	12.6	3.3	1.38	3.42	3.98	14.1	1.6
Variety PR 115	81.4	71.5	57.4	12.0	3.3	1.45	3.35	3.96	14.2	0.4
CD (p=0.05)	0.3	0.4	NS	0.7	NS	NS	NS	NS	-	-
Date of direct seeding and transplanting										
1 June (direct seeded)	81.7	71.2	55.7	11.2	3.4	1.38	3.37	4.06	10.9	1.0
15 June (direct seeded)	82.1	71.2	56.3	11.6	3.4	1.42	3.37	4.00	13.0	1.3
30 June (direct seeded)	81.6	71.2	55.7	12.1	3.3	1.41	3.38	3.97	14.2	1.7
15 July (direct seeded)	81.5	70.3	56.6	12.9	3.2	1.40	3.29	3.93	16.1	1.3
21 June (transplanted)	82.3	73.3	61.5	11.8	3.4	1.36	3.39	3.86	12.5	0.7
6 July (transplanted)	82.6	73.0	62.1	12.1	3.4	1.43	3.40	3.87	13.6	1.0
21 July (transplanted)	82.3	72.4	60.7	12.2	3.3	1.47	3.39	4.08	13.9	1.3
5 Aug (transplanted)	81.6	71.4	59.1	12.3	3.2	1.46	3.33	3.83	14.2	1.3
CD (p=0.05)	0.7	0.8	3.1	0.6	0.1	NS	NS	NS	-	-

All interactions: NS

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Table 3. Economics and sheath blight severity of rice as influenced by hybrids and date of direct seeding and transplanting

Treatments	Gross Returns (Rs. ha^{-1})	Net Returns (Rs. ha^{-1})	B-C ratio	Sheath blight severity (%)
Hybrids/Variety				
Hybrid SVH 5	54434.0	25982.3	1.91	17.8
Hybrid SVH 26	55491.2	27039.6	1.95	19.3
Variety PR 115	52019.7	26668.0	2.03	19.1
CD (p=0.05)	NS	NS	NS	-
Date of direct seeding and transplanting				
1 June (direct seeded)	54427.0	29025.9	2.14	46.0
15 June (direct seeded)	53529.1	28278.2	2.12	42.7
30 June (direct seeded)	48143.3	23117.1	1.93	2.3
15 July (direct seeded)	37763.5	12887.3	1.53	1.3
21 June (transplanted)	69361.6	39213.3	2.30	42.3
6 July (transplanted)	67893.6	37970.8	2.27	11.3
21 July (transplanted)	54303.7	24830.7	1.84	1.3
5 Aug (transplanted)	46431.2	17183.1	1.60	0.0
CD (p=0.05)	5140	5139	0.19	-

All interactions: NS

aroma score (1.7) was recorded in crop direct sown on 30 June.

Effect on Economic Returns

The gross returns were not-significantly influenced by hybrids and variety. Among dates of direct seeding and transplanting, higher gross returns were obtained in transplanted rice as compared to direct seeding. Crop transplanted on 21 June recorded highest gross returns of Rs. 69361 ha^{-1} that were statistically at par with gross returns recorded in 6 July transplanted crop but significantly higher as compared to all other dates.

Net returns were not significantly influenced by hybrids and variety. However maximum net returns of Rs. 27039 ha^{-1} were recorded in hybrid SVH 26. Crop transplanted on 21 June recorded highest net returns (Rs. 39213 ha^{-1}) and it was statistically at par with net returns recorded in 6 July transplanted crop but significantly higher than net returns from crop sown/transplanted on all other dates (Table 3). Baloch *et al.* (2006) also reported that 20 June transplanted crop given highest net returns over crop transplanted on later dates. In general, direct seeded crop recorded less net returns than transplanted crop.

Benefit cost ratio (B: C ratio) was not-significantly influenced by hybrids, whereas, it was influenced significantly by dates of direct seeding and transplanting. The highest Benefit Cost Ratio of 2.30 was recorded for crop transplanted on 21 June that was statistically at par with B: C ratio obtained in crop transplanted on 6 July and crops direct seeded on 1 and 15 June but it was significantly better as compared to all other dates. In direct seeded crop Bashir *et al.* (2010) also reported maximum B: C ratio in 20 June sown crop.

Effect on Sheath Blight Incidence

The mean maximum sheath blight severity (19.3%) was recorded in hybrid SVH 26 followed by 19.1% in PR 115 and lowest (17.8 %) in hybrid SVH 5. Sheath blight was comparatively more severe in direct seeded rice as compared to transplanted crop. In both methods of rice crop establishment, the disease severity decreased continuously with delay in sowing and transplanting. Jin-liang *et al.* (2011) also reported significant decrease in sheath blight occurrence and injury with postponement in date of direct seeding or transplanting.

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Indian Journal of Ecology

Effect of Irrigation and Nitrogen Levels on Growth, Yield and Hydrocyanic Acid (HCN) Content of Forage Sorghum (*Sorghum bicolor*) under Different Cutting Managements

Amandeep Saini [1] and U.S. Tiwana

Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, India 141 001
[1]Corresponding author:aman.saini@mail.utoronto.ca (Deptt. of Physical and Environmental Sciences, University of Toronto, Canada)
E-mail: aman.saini@mail.utoronto.co.

Abstract: The study was carried at Forage Research Farm, Department of Plant Breeding & Genetics, Punjab Agricultural University, Ludhiana during summer season, 2008. The experiment comprised of three levels of nitrogen and last irrigation along with three harvesting stage. With harvesting at 100 days after sowing (DAS), green fodder yield was 88.6 and 21.7 per cent higher and dry matter yield was 274.2 and 52.5 per cent higher over 50 and 75 DAS along with significant reduction in HCN content. On the basis of findings, it was concluded that sorghum can be harvested at 100 days after sowing for higher good quality green fodder production with the application of 125 % nitrogen of recommended dose and last irrigation at 7 days before harvest.

Key Words: Sorghum, Green matter yield, Dry matter yield, Nitrogen rate, Irrigation, Hydrocyanic acid content, Cutting stage

Sorghum (*Sorghum bicolor*) is the principal non legume fodder crop grown all over the India under poor management. As forage, it is fast growing, palatable, nutritious and utilized as silage and hay besides fresh feeding. Agronomic techniques are very helpful to obtain its higher productivity of good quality herbage to fulfill feeding requirement of dairy animals. Being an exhaustive crop, sorghum suffers heavily if proper amount of fertilizer is not applied. All the crops in general and fodders in particular, use nitrogen in large quantity as nitrogen is one of the most important factors, which influences the yield and quality of fodders. Scheduling of irrigation is very important agronomic practice particularly in case of fodders like sorghum as uptake of water is involved in solubilization and transportation of nutrient elements from soil to the plant system.

For better efficiency of live stock, only quantitative production is not important, but the quality also plays its role. Therefore, harvesting stage of crop is also very important for good quality fodder as the succulency; dry matter and HCN content of fodder are largely affected by harvesting stage of the crop.

MATERIAL AND METHODS

The field experiment was conducted during *kharif* 2008 at Forage Research Farm, Department of Plant Breeding & Genetics, Punjab Agricultural University, Ludhiana. Twenty seven treatment combinations comprising three harvesting stages (50, 75 and 100 days after sowing), three irrigation scheduling (7, 14 and 21 days before harvest) and three levels of nitrogen (75, 100 and 125 per cent nitrogen of the recommended dose) were tested in slit plot design with three replications. The soil of experimental field was loamy sand in texture, low in organic carbon and available nitrogen and high in available phosphorus and potassium. The values of pH and electrical conductivity of the experimental field were 7.5 and 0.20 (dsm^{-1}) respectively.

Sorghum variety HC 308 was sown in lines 22 cm apart using seed rate of 62.5 kg ha^{-1}. Full dose of 20 kg P_2O_5 ha^{-1} and half dose of nitrogen was applied at the time of sowing and remaining half of nitrogen was applied after four weeks as per treatments.

HCN was determined from fresh plant samples by using the method of Hogg and Ahlgren (1942).

RESULTS AND DISCUSSION

Growth parameter

Irrigation and nitrogen levels did not significantly influence the plant population of sorghum at different growth stages (Table 1). This could be due to the fact that sorghum does not have capacity to produce tillers. On the other hand, plant height increased whereas leaf stem ratio decreased with the advancement of plant age. Plant height at 100 DAS was significantly higher than 50 DAS and it was due to the plants got sufficiently more time for their growth and development. The leaf-stem ratio was significantly highest at 50 DAS and decreased with advancement of age. Increase in stem weight due to stem elongation and increase in stem diameter is the main reason of decrease in leaf-stem ratio with advancement of harvesting age.

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Plant height and leaf stem ratio were also significantly varied by scheduling of last irrigation. Both parameters decreased with delay in last irrigation. Maximum plant height (206.7 cm) and leaf stem ratio (0.75) were recorded when last irrigation was given at 7 days before harvesting as compared to last irrigation applied at 14 and 21 days before harvest. The adequate moisture content increases the cell elongation and uptake of nutrients resulting in more plant height and leaf stem ratio. Vannavong and Detpiratmongkol (2008) also reported increase in weight by relieving water stress.

Significant increase in leaf-stem ratio and plant height was observed with each increment in nitrogen level up to 125 per cent nitrogen of the recommended dose. Application of 125 per cent nitrogen of the recommended dose significantly increased plant height by 17 and 5.8% and leaf stem ratio by 46.9 and 20 % over 75 and 100% of the recommended dose, respectively. Agrawal *et al.* (2005) also found highest leaf-stem ratio (0.59) with highest dose of nitrogen.

Fodder Yield

Harvesting stage influenced the fodder yield of sorghum significantly. Sorghum crop harvested at 100 DAS produced highest green fodder and dry matter yield of 597 and 186 qha^{-1} respectively (Table 1). Increase in fodder yield with delay in harvest stage from 50 to 100 DAS was due to more growth of yield attributing characters like plant height, stem diameter, more number of leaves per plant etc. Cakmakc *et al.* (1999) revealed that fresh weight of plants increased from panicle initiation stage to the hard dough stage. Increase in dry matter with the advancement of age was due to more deposition of fibrous material in plant parts.

Significantly higher green fodder and dry matter yield were obtained when the crop was irrigated at 7 days before harvest. Maximum green fodder yield (500 q ha^{-1}) and dry matter yield (137 q ha^{-1}) was obtained with last irrigation at 7 days before harvest which was 4.8 and 17% and 14.9 and 30.7% higher than the irrigation applied at 14 and 21 days before harvest, respectively. Irrigation contributed to increase in yield because it helps in the absorption and translocation of nutrients from the soil to the growing parts of the plants and moreover increases moisture content of plant parts.

The yield increased significantly with the increase in dose of nitrogen. The highest green fodder yield (520 q ha^{-1}) and dry matter yield (126 qha^{-1}) was recorded with the application of 125 per cent nitrogen of the recommended dose. Significantly higher yield at highest nitrogen dose might be associated with high photosynthetic activity, vigorous growth, better plant height, higher carbohydrate utilization and increase in fodder succulence.

Hydrocyanic acid content

The HCN content was highest at 50 DAS and decreased rapidly with the advancement of crop stage upto 100 DAS (Table1). The highest HCN content observed at 50 DAS was 172.7 ppm which reduced to 88.3 ppm at 75 DAS and

Table 1. Effect of harvesting stage, time of last irrigation and level of nitrogen on growth parameters, yield and HCN content

Treatment	Plant population (per m row length)	Plant height (cm)	Leaf - stem ratio	Green fodder yield (qha^{-1})	Dry matter yield (qha^{-1})	HCN content (ppm)
Harvesting stage (DAS= days after sowing)						
50 DAS	15	117.5	0.93	317	49.7	172.7
75 DAS	15	206.9	0.49	491	122	88.3
100 DAS	15	255.6	0.38	597	186	42.9
CD (p = 0.05)	NS	6.2	0.03	27.7	9.7	1.2
Last Irrigation						
7 days before harvest	14	206.7	0.74	500	136	68.2
14 days before harvest	15	192.2	0.57	477	118	96.2
21 days before harvest	15	181.2	0.50	427	104	139.6
CD (p = 0.05)	NS	6.2	0.03	27.7	9.7	1.2
Nitrogen levels						
75% of the recommended	15	177.1	0.49	409	111	70.1
100% of the recommended	16	195.7	0.60	476	120	107.5
125% of the recommended	15	207.2	0.72	520	126	126.4
CD (p = 0.05)	NS	2.8	0.009	8.4	2.1	0.75

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42.9 ppm at 100 DAS. The corresponding values at 100 and 75 per cent of recommended dose were 107.5 and 70.1 ppm and the results were in accordance with study done by Sultan (2003). The decrease in HCN content in later stages might be due the proportional increase in weight of plant parts that contain low HCN content i.e. stem and this is confirmed by the trend in leaf-stem ratio which narrowed down as the plant advanced in age.

Water stress affected HCN content significantly. HCN content was lowest (68.2 ppm) with last irrigation at 7 days before harvest as compared to 96.2 and 139.6 ppm with 14 and 21 days before harvest, respectively. Irrigation affected the HCN content because of the dilution effect in plant parts.

Nitrogen application influenced the HCN content in forage sorghum. With each increment in dose of nitrogen, HCN content increased up to the highest level of nitrogen with the maximum of 126.4 ppm at 125 per cent nitrogen of the recommended. HCN increased with increase in nitrogen because at higher nitrogen rates the absorption also increased in plant in the forms of nitrates. It later on get changed to hydrocyanic acid as an intermediate stage between nitrates and amino acids in the formation of proteins and this could have possibly increased HCN content. As soon as HCN is formed, it combines with glucose and benzaldehyde to form a non toxic glucoside. However, it accumulates in plant if conditions are not favourable for rapid and complete synthesis of protein. Wheeler *et al.* (1980) also found that HCN content was increased by 28 % by nitrogen fertilization.

Sorghum crop harvested at 100 DAS produced highest green fodder and dry matter yield of 597 and 186 qha^{-1} respectively. But HCN content decreased with advancement of growth stage of the crop. The application of 125 per cent of recommended nitrogen and irrigation applied 7 days before harvesting also significantly increased fodder yield and improved the quality of sorghum fodder over other levels.

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Long-term Effect of Cropping Systems on Fe and Mn Fractions in Alluvial Soils of North-West India

Gurpreet Singh, S.S. Dhaliwal*, U.S. Sadana and S.S. Walia

Department of Soil Science, Punjab Agricultural University, Ludhiana- 141004
**E-mail: ssdhaliwal@pau.edu*

Abstract: The present research study has been conducted with a prime objective to investigate the chemical fractions of Fe and Mn under 10 cropping systems in alluvial soils of Punjab. Surface (0-15 cm) soil samples were collected from an ongoing field experiment (in progress since 2000) with 10 cropping systems at Research Farm of Department of Agronomy, Punjab Agricultural University, Ludhiana. These soil samples were analyzed for total Fe, and Mn and their chemical fractions using atomic absorption spectrophotometer (Varion AAS-FS 240 Model). Among chemical fractions, higher levels of Fe and Mn (WSEX and SpAd) were reported in the rice-wheat cropping system. Among fractions, SpAd, held on organic sites, oxide bound and amorphous fractions of Fe and Mn contributed towards plant available (water soluble and exchangeable) fraction.

Key Words: Cropping systems, Fe and Mn Alluvial soils

The study of various fractions of Fe and Mn present in soil and conditions under which these become available to plants is pre-requisite in assessing their availability to plants. It is important to know the relationship between chemical fractions of micronutrients in the soil and their uptake by the crop. Under continuous cropping system, micronutrients are generally considered to be present in association with soil solution, organic and inorganic solid phases and this association is often referred to as speciation (Bahera *et al.* 2008), thus forming their various chemical fractions such as water soluble plus exchangeable, specifically adsorbed, and those associated with free calcium carbonate, oxide surfaces, soil organic matter and minerals. The alternate flooding (reduced stage) in rice and upland (oxidized stage) conditions in wheat effects transformation of Fe and Mn from one chemical forms to another. Sekhon *et al.* (2006) reported that cultivation of rice-wheat continuously for 7 years without any Fe and Mn fertilization did not deplete the amount of micronutrient in various fractions from their original levels. Dhaliwal (2008) reported that green manure and soil applied Mn to rice – wheat system increased the DTPA-extractable, water soluble plus exchangeable and Mn specifically adsorbed on the inorganic sites whereas, Mn held on organic sites and oxide bound surfaces decreased. The inclusion of leguminous crop like cowpea increased the levels of Fe and Mn in the soil under different cropping systems (Patel *et al.* 2009). FYM proved to be the most efficient in enhancing availability of Fe and Mn as compared to GM and leguminous crops used under different cropping systems. Increase in water soluble plus exchangeable fractions of Fe and Mn (2.5, 0.39, 5.4 and 4.1 mg kg^{-1} respectively) with FYM amended plots at the end of 5 cycle of rice-wheat rotation. Saha *et. al.* (2000) reported more than 85 per cent of applied Cu was distributed in WSEX, OM, and AFeOX fractions and it was due to application of organic matter in soil which mobilized applied Cu from OM to AMOX fraction and reduced net transformation into residual fraction. Keeping these points in view the present research study was planned with the objectives to know study the chemical pools of Fe and Mn in the surface soils under different cropping sequences.

MATERIAL AND METHODS

The experiment was conducted in a fixed layout since its beginning with ten cropping systems and different crop combinations were mentioned in Table 1. Nitrogen (N), phosphorus (P) and potassium (K) fertilizers were applied to different crops as per recommendations given by Punjab Agricultural University, Ludhiana (Anonymous 2009-10). The soil is slightly alkaline in reaction (pH 7.2), normal in soluble salt concentration (EC 0.40 dSm^{-1}), low in OC (0.38 %), low in available nitrogen, medium in available phosphorus and low in available potassium.

Sequential Extraction Procedure to Determine Chemical Pools (Fractions) of Fe and Mn in Soil Samples

The processed surface (0-15 cm) soil samples were taken before sowing *Kharif* crops used to fractionation of Fe and Mn into following chemical forms as per sequential procedure described below:

Water Soluble plus Exchangeable Fraction (WSEX): Five grams of soil was shaken with 20 ml of 0.005 M Pb $(NO_3)_2$ in 100 ml centrifuge tubes for fifteen minutes at 25°C in Orbital shaker and mixture was centrifuged for ten minutes at 6000 rpm the supernatant filtered, separated and stored

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Table 1. Different crops and cropping systems followed in long term experiment

Treatment	Cropping systems	Seasons		
		Kharif	*Rabi*	Summer
T_1	Rice-Wheat	Rice	Wheat	-
T_2	Maize-Wheat	Maize	Wheat	-
T_3	Maize-Wheat-Mungbean	Maize	Wheat	Mungbean
T_4	Maize-Potato-Mungbean	Maize	Potato	Mungbean
T_5	Maize-Potato-Onion	Maize	Potato	Onion
T_6	Cotton-Wheat (late sown)	Cotton	Wheat	-
T_7	Cotton-African Sarson	Cotton	African sarson	-
T_8	Cotton-Gobhi Sarson	Cotton	Gobhi sarson	-
T_9	Groundnut-Toria+Gobhi sarson	Groundnut	Toria+Gobhi sarson	-
T_{10}	Groundnut-Potato-Bajra fodder	Groundnut	Potato	Bajra fodder

for analysis. (Manchanda *et. al.* 2006). The Reagent 0.005 M $Pb(NO_3)_2$ is prepared by dissolving 1.65 gm of lead nitrate in one litre adjusting the pH of solution to 6.8 by 0.5M ammonium acetate (NH_4AC) which is prepared by dissolving 38.5 gm of ammonium acetate in 1 litre.

Specifically Adsorbed (SpAd): The soil residue from water soluble plus exchangeable fraction was shaken with 20 ml of 0.05M $Pb(NO_3)_2$ for 2 hours at 25°C in orbital shaker and ; the sample was, thereafter, centrifuged ten minutes at 6000 rpm and the supernatant filtered (Iwaski *et al.* 1993). The sequential extraction continued in the remaining of the soil sample The Reagent 0.05 M $Pb(NO_3)_2$ is prepared by dissolving 16.56gm lead nitrate in one litre adjusting the pH of solution to 6.0 by 0.5M ammonium acetate (NH_4OAC)

Mn-Oxide Bound Fraction (MnOX): To the remaining soil sample 20.0 ml of $NH_2OH.HCl$ (hydroxylamine hydrochloride) 0.1 mol l^{-1}, at pH 2.0 were added, and the mixture was shaken for 30 min, centrifuged and filtered; the separated supernatant was stored for analysis (Chao, 1972). The reagent 0.1 M $NH_2OH.HCl$ in 0.01M HNO_3 is prepared by dissolving 6.95gm of ((hydroxylamine hydrochloride) $NH_2OH.HCl$ and 0.625 Nitric acid (HNO_3) in water and make the volume to one liter.

Amorphous Fe-Oxides Bound (AFeOX): To the Mn-Oxide Bound Fraction free soil sample 20.0 ml of $NH_2OH.HCl$ (hydroxylamine hydrochloride) 0.1 mol L^{-1} plus HCl 0.25 mol l^{-1}, at pH 1.3 were added, and the mixture was shaken for 30 min at 25°C in orbital shaker, centrifuged and filtered; the separated supernatant was stored for analysis (Chao and Zhau, 1983). The reagent 0.25 M $NH_2OH.HCl$+0.25 M HCl is prepared by dissolving 17.37 gm of Hydroxyl amino chloride ($NH_2OH.HCl$) in water and pour 21 ml of Hydrochloric acid (HCl) in it and make the volume of solution to one liter.

Table 2. Fertilizer application to different crops as per recommendation of *Package and practices of Kharif and Rabi* crops, PAU, Luhiana

Crop	Variety	Recommended dose of fertilizer (kg ha^{-1})			FYM(t ha^{-1})
		N	P_2O_5	K_2O	
Rice	PR 114	120	30	30	-
Wheat	PBW 343	120	60	30	-
Wheat (late sown)	PBW 373	120	60	30	-
Maize	Paras	120	60	30	10
Cotton	LH - 1556	30	12	-	-
Groundnut	M - 522	15	20	25	-
Potato	Kufri Chandermukhi	187	62	62	10
Gobhi sarson	GSL-1	100	30	-	-
African sarson	PC - 5	100	30	-	-
Toria+Gobhi sarson	TL-15 + GSL-1	62+100	20+30	-	-
Onion	Punjab Naroya	100	50	50	-
Mungbean	SML- 668	12	40	-	-
Bajra fodder	PCB - 15	50	-	-	-

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Crystalline Fe-Oxides Bound (CFeOX): To the AFeOX free soil sample 20.0 ml of 0.25 M $NH_2OH.HCl$ +0.25 M HCl + ascorbic acid 0.01 mol l^{-1}, at pH 1.21 were added, the mixture was heated with boiling water (100°C) in a beaker placed on hot plate for 30 minutes, shaking from time to time; thereafter centrifuged and filtered; the separated supernatant was stored for analysis (Manchanda *et al.* 2006). The sequential extraction continued in the remaining of the soil sample. The reagent 0.25 M $NH_2OH.HCl$ +0.25 M HCl +0.1 M ascorbic acid is prepared by dissolving 17.37 gm of Hydroxyl amino chloride ($NH_2OH.HCl$) in water, pour 21 ml of Hydrochloric acid (HCl) and 17.61gm of ascorbic acid in it and make the volume of solution to one litre.

Organically Bound Fraction (OM): To the CFeOX free soil sample was shaken with 20 ml of 1 % $Na_4P_2O_7$ for one hour at 25°C in Orbital shaker and mixture was centrifuged for ten minutes at 6000 rpm the supernatant filtered, separated and stored for analysis (Raja and Iyengar, 1986). The reagent prepared by dissolving 4.46 gm of sodium-pyrophosphate in one liter.

Residual Fraction (RES): Residual fraction (cation) = Total content (cation) - sum of all fractions (cation)

The amount of Mn and Fe in different fractions was estimated using atomic absorption spectrophotometer.

Total Fe and Mn : For total elemental analysis of Fe and Mn a 0.5 gm sample of soil was digested with 5 ml of hydrofluoric acid (HF), 1ml of perchloric acid ($HClO_4$) and 5-6 drops of nitric acid (HNO_3) in a 30 ml capacity platinum crucibles (Page *et al.* 1982). When the soil became completely dry in the crucible the residue in the crucible was completely dissolved in 6 N HCl. The contents of the crucible were transferred to 100 ml volumetric flask with double distilled water. The digests were analyzed for total Fe and Mn after appropriate dilutions with atomic absorption spectrophotometer. The results of the elemental analysis were reported on an oven-dry weight basis.

Statistical Analysis

Micronutrient cations were subjected to randomized complete block design analysis of variance. Critical difference (CD) was used to compare the treatments effects at P<0.05.The statistical analysis was done with the help of method described by Panse and Sukhatme, (1985).

RESULTS AND DISCUSSION

Chemical Fractions of Fe in Different Cropping Systems

Significantly higher levels of Fe in WSEX (11.2 mg kg^{-1}), SpAd (6.40 mg kg^{-1}), MnOX (11.3 mg kg^{-1}) and AFeOX (44.22 mg kg^{-1}) fractions were observed in rice-wheat cropping system as compared to maize-wheat and cotton-wheat cropping systems (Table 4). The higher levels of Mn in these fractions under rice-wheat cropping system may be due to effect of submergence. On the other hand concentrations of CFeOX-Fe (446.2 mg kg^{-1}) and OM-Fe (82.50 mg kg^{-1}) were significantly higher in cotton-wheat cropping system as compared to rice-wheat and maize-wheat cropping systems. The higher level of total-Fe (1.74%) was observed in maize-wheat cropping system as compared to rice-wheat cropping system. Similar results were observed by Singh *et al.* (1988) and Randhawa and Singh, (1997), who reported that about 52 per cent of the total soil Fe was presented in RES fraction and about 41 per cent of the total Fe was associated with CFeOX fraction. Similarly, Nayyar and Chhibba (2000) reported that the prevalence of alternative oxidized and reduced conditions under rice-wheat system caused a decline in the content of CFeOX form concomitant with an increase in the easily reducible AFeOX form of these micronutrients leading to their increased availability.

Table 3. Basic properties of experimental soil under different cropping systems

Treatment	Particle (%) distribution				Basic soil parameters					
	Sand	Silt	Clay	Texture	pH	ECdSm^{-1}	OC%	N	P	K
								(kg ha^{-1})		
T_1	75	19	6	LS	7.61	0.24	0.44	220.5	40.3	122.4
T_2	76	16	8	LS	7.71	0.31	0.50	235.1	44.7	151.2
T_3	80	11	10	LS	7.64	0.32	0.56	242.4	48.5	146.2
T_4	77	14.5	8.5	LS	7.75	0.33	0.62	260.2	54.2	208.2
T_5	78	12.5	9.5	LS	7.80	0.32	0.64	264.1	52.5	170.0
T_6	76	14.2	9.8	LS	7.72	0.22	0.51	255.4	43.5	124.0
T_7	75	17	8	LS	8.08	0.24	0.54	252.3	42.9	128.0
T_8	78	13.7	8.3	LS	7.91	0.25	0.57	250.1	41.4	136.5
T_9	76	17	7	LS	7.92	0.24	0.52	247.3	40.7	145.0
T_{10}	77	16.2	6.8	LS	8.03	0.26	0.57	245.3	45.0	140.3
Initial	78	15.5	7.1	LS	7.20	0.40	0.38	71.7	41.4	89.6

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Table 4. Different chemical fractions of Fe in surface soils (0-15cm) under different cropping systems

Treatment	Chemical fractions of Fe							
	WSEX	SpAd	MnOX	AFeOX	CFeOX	OM	RES	Total
	Concentration of Fe(mg kg^{-1})						Concentration (%)	
T_1	11.2	6.40	11.37	44.22	395.25	57.25	1.68	1.73
T_2	8.2	5.21	9.30	40.30	422.6	74.75	1.68	1.74
T_3	7.9	5.52	8.67	36.35	471.7	67.75	1.58	1.64
T_4	8.9	5.70	6.35	33.27	381.2	86.75	1.57	1.62
T_5	8.5	5.51	6.37	31.35	363.9	79.20	1.68	1.72
T_6	6.1	4.61	7.70	28.30	446.2	82.50	1.68	1.73
T_7	9.2	4.81	6.50	26.12	430.9	63.75	1.74	1.80
T_8	9.5	4.91	6.65	28.72	412.1	58.75	1.63	1.68
T_9	9.0	3.93	7.52	30.60	402.4	50.50	1.70	1.76
T_{10}	5.9	4.20	7.35	28.25	392.6	53.20	1.63	1.68
Mean	8.44	5.08	7.78	32.74	411.9	67.39	1.65	1.71
CD (p=0.05)	0.21	0.91	0.33	0.36	2.90	2.47	0.20	0.12

In maize based cropping systems, significantly higher level of WSEX (8.9 mg kg^{-1}), SpAd (5.70 mg kg^{-1}) and OM (86.75 mg kg^{-1}) fractions of Fe were observed in maize-potato-mungbean cropping system as compared to maize-potato-onion, maize-wheat and maize-wheat-mungbean cropping systems. Higher content in maize-potato-mungbean cropping system may be due to addition of FYM before sowing of maize and potato crop. Similar results were observed by Maskina *et al.* (1998), who observed an increase in WSEX fraction of Fe with addition of FYM. Further, the content was higher in maize-potato-mungbean system which may be due to higher addition of plant biomass in soil as compared to maize-potato-onion cropping system. On the other hand levels of Fe in MnOX (9.30 mg kg^{-1}) and AFeOX (40.30 mg kg^{-1}) fractions were significantly higher in maize-wheat cropping system as compared to maize-potato-mungbean and maize-potato-onion cropping systems. Significantly higher concentration of CFeOX-Fe (471.7 mg kg^{-1}) fraction was observed in maize-wheat-mungbean as compared to maize-wheat, maize-potato-mungbean and maize-potato-onion cropping systems. The levels of RES-Fe (1.68%) and Total-Fe (1.74%) fractions were significantly higher in maize-wheat cropping system as compared to maize-wheat-mungbean (1.58 and 1.64 % respectively) and maize-potato-mungbean cropping systems. Similar results were observed by Behera *et al.* (2009). Similarly, Agbenin, (2003) concluded that sole application of FYM in combination with NPK rather than NPK alone can mobilize non-labile Mn and Fe sources into labile and plant available forms of Fe and Mn in a savanna Alfisol.

Cotton-gobhi sarson cropping system reported higher concentration of Fe as 9.5, 4.9 and 28.72 mg kg^{-1}respectively, in WSEX, SpAd and AFeOX fractions respectively as compared to cotton-african sarson and cotton-wheat cropping systems. Significantly higher levels of Fe in MnOX (7.70 mg kg^{-1}), CFeOX (446.2 mg kg^{-1}) and OM (82.50 mg kg^{-1}) fractions were observed in cotton-wheat cropping system as compared to cotton-gobhi sarson and cotton-african sarson cropping systems. The levels of RES-Fe (1.74%) and Total-Fe (1.80%) fractions were significantly higher in cotton-african sarson as compared to cotton-gobhi sarson and cotton-wheat cropping systems. The significantly higher levels of Fe in WSEX (9.0 mg kg^{-1}), AFeOX (30.60 mg kg^{-1}) and CFeOX (402.4 mg kg^{-1}) fractions were reported in groundnut-toria+gobhi sarson cropping system as compared to groundnut-potato-bajra (fodder) cropping system. Similar results were obtained by Agbenin, (2003), who reported that application of FYM increased AMOR-Fe, but decreased CRYST-Fe which was probably by the inhibition of Fe crystallization. Similarly, FYM application increased MnOX-Fe, AMOR-Fe and EXCH-Fe, but decreased RES-Fe fraction. On the other hand concentrations of SpAd (4.20 mg kg^{-1}) and OM (53.20 mg kg^{-1}) fractions of Fe were significantly higher in groundnut-potato-bajra (fodder) as compared to groundnut-toria+gobhi sarson cropping system. Groundnut-toria+gobhi sarson cropping system showed significantly higher concentration of RES-Fe (1.70%) and Total-Fe (1.76%) fractions as compared to groundnut-potato-bajra (fodder) and groundnut-toria+gobhi sarson cropping system. The inclusion of short duration crops like mungbean, toria and gobhi sarson in main cropping systems helped to the increased levels of Fe in all chemical fractions.

Chemical Fractions of Mn in Different Cropping Systems

Significantly higher concentration of Mn was observed in WSEX (5.6 mg kg^{-1}) and SpAd (3.82 mg kg^{-1}) fractions in

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rice-wheat cropping system as compared to other cropping systems (Table 5). The levels of Mn in WSEX (5.6 mg kg^{-1}), SpAd (3.82 mg kg^{-1}), MnOX (19.2 mg kg^{-1}) and AFeOX (49.3 mg kg^{-1}) fractions were significantly higher in rice-wheat cropping system as compared to maize-wheat (4.7, 3.11, 18.5 and 47.3 mg kg^{-1}respectively) and cotton-wheat (4.5, 2.72, 15.4 and 39.4 mg kg^{-1} respectively) cropping systems. On the other hand higher levels of Mn of CFeOX (46.0 mg kg^{-1}) and total (386.3 mg kg^{-1}) fractions were observed in maize-wheat cropping system as compared to rice-wheat (40.7 and 380.0 mg kg^{-1} respectively) and cotton-wheat (22.7and 362.6 mg kg^{-1}respectively) cropping systems. Cotton-wheat cropping system showed higher level of Mn in RES fraction (260.6 mg kg^{-1}) as compared to rice-wheat (245.6 mg kg^{-1}) and maize-wheat (248.9 mg kg^{-1}) cropping systems. The higher level of Mn in these fractions under rice-wheat cropping system may be due to effect of submergence. Similar results by Dhaliwal (2008) reported that rice–wheat cropping system increased the levels of Mn in WSEX and SpAd on the inorganic sites whereas, Mn held on organic sites and oxide bound surfaces decreased. Similarly, Singh *et al.* (1988) and Randhawa and Singh, (1997)reported that about 53 per cent of the total soil Mn was present in RES fraction and about 11 per cent of the total Mn was associated with CFeOX fraction. Similarly Nayyar and Chhibba, (2000) reported that the prevalence of alternative oxidized and reduced conditions under rice-wheat system caused a decline in the content of CFeOX forms of Mn concomitant with an increase in the easily reducible AFeOX forms of these micronutrients leading to their increased availability.

Maize-potato-mungbean cropping system reported higher levelsof Mn in WSEX (5.2 mg kg^{-1}), SpAd (3.35 mg kg^{-1}) and OM (19.3 mg kg^{-1}) fractions as compared maize-wheat-mungbean (5.0, 3.22 and 15.9 mg kg^{-1}) and maize-wheat (4.7, 3.11 and 16.6 mg kg^{-1}) cropping systems. On the other hand higher concentrations of Mn in AFeOX (47.3 mg kg^{-1}), CFeOX (46.0 mg kg^{-1}), and total (386.3 mg kg^{-1}) fractions were observed in maize-wheat cropping system as compared to other maize based cropping systems. The levels of MnOX-Mn (19.8 mg kg^{-1}) and RES-Mn (250.4 mg kg^{-1}) fractions were significantly higher in maize-potato-onion cropping system as compared to maize-potato-mungbean (19.7 and 243.6 mg kg^{-1}) and maize-wheat-mungbean (18.3 and 233.8 mg kg^{-1}) cropping systems. The higher content in maize-potato-mungbean may be due to addition of FYM in soil before sowing of maize and potato crops. Similar results reported by Maskina *et al.* (1998), who observed an increase in WSEX fractions of Mn with addition of FYM under maize-wheat cropping system. Similar results were observed by Behera and Singh, (2009).

Higher concentrations of Mn in WSEX (4.5 mg kg^{-1}), MnOX (16.5 mg kg^{-1}) and OM (18.2 mg kg^{-1}) were observed in cotton-gobhi sarson cropping system as compared to cotton-wheat (4.3, 15.4 and 17.1 mg kg^{-1}respectively) and cotton-african sarson (4.0, 15.9 and 17.6 mg kg^{-1}respectively) cropping systems. On other hand levels of Mn were 3.0, 42.4 and 31.2 mg kg^{-1} respectively, in SpAd, AFeOX and CFeOX fractions respectively, were higher in cotton-african sarson cropping system as compared to other cotton based cropping systems. Higher levels of RES-Mn (260.6 mg kg^{-1}) and total-Mn (362.5 mg kg^{-1}) fractions were reported in cotton-wheat cropping system as compared to cotton-african sarson (231.3 and 345.5 mg kg^{-1}) and cotton-gobhi sarson (242.4 and 355 mg kg^{-1}) cropping systems. The levels of Mn in WSEX (5.1 mg kg^{-1}), CFeOX (28.3 mg kg^{-1})

Table 5. Different chemical fractions of Mn in surface soils (0-15cm) under different cropping systems

Treatment	Chemical fractions							
	WSEX	SpAd	MnOX	AFeOX	CFeOX	OM	Residual	Total
	Concentration of Mn (mg kg^{-1})							
T_1	5.6	3.82	19.2	49.3	40.7	15.6	245.6	380.0
T_2	4.7	3.11	18.5	47.3	46.0	16.6	248.9	386.3
T_3	5.0	3.22	18.3	38.2	31.5	15.9	233.8	346.3
T_4	5.2	3.35	19.7	36.1	27.0	19.3	243.6	351.5
T_5	5.0	3.27	19.8	35.3	24.0	16.4	250.4	354.2
T_6	4.3	2.72	15.4	39.4	22.7	17.1	260.6	362.5
T_7	4.0	3.0	15.9	42.4	31.2	17.6	231.3	345.5
T_8	4.5	2.84	16.5	41.4	29.3	18.2	242.4	355.0
T_9	5.1	2.21	17.1	30.4	28.3	17.8	260.1	361.2
T_{10}	4.2	2.68	17.3	30.5	26.5	16.3	279.7	377.5
Mean	4.8	3.02	17.8	39.0	30.7	16.9	249.6	362
CD (p=0.05)	0.32	0.014	0.018	0.56	1.66	0.20	12.8	NS

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Table 6. Correlation matrix between different chemical fractions of Fe and Mn

Different fractions	Fe fraction							
	WSEX	SpAd	MnOX	AFeOX	CFeOX	OM	Res.	Total
SpAd	0.57							
MnOX	0.32	0.47						
AFeOX	0.47	0.73*	0.86**					
CFeOX	-0.26	-0.13	0.22	-0.09				
OM	-0.22	0.37	-0.24	0.03	-0.03			
RES	0.17	-0.27	0.08	-0.15	-0.04	-0.25		
Total	0.17	-0.30	0.10	-0.13	0.03	-0.28	0.99**	
	Mn fraction							
	WSEX	SpAd	MnOX	AFeOX	CFeOX	OM	Res.	Total
SpAd	0.50							
MnOX	0.79**	0.66*						
AFeOX	0.21	0.64*	0.07					
CFeOX	0.41	0.43	0.27	0.76*				
OM	-0.40	-0.61	-0.54	-0.23	-0.34			
RES	-0.09	-0.50	-0.14	-0.54	-0.30	-0.09		
Total	0.32	0.08	0.15	0.31	0.59	-0.41	0.55	

Correlation coefficient significant at 5% = 0.63*

Correlation coefficient significant at 1% = 0.76**

$^{-1}$) and OM (17.8 mg kg^{-1}) fractions were significantly higher in soil under groundnut-toria+gobhi sarson cropping system as compared to groundnut-potato-bajra (fodder) (4.2, 26.5 and 16.3 mg kg^{-1}respectively) cropping system. On the other hand significantly higher concentration of Mn in SpAd (2.68 mg kg^{-1}), MnOX (17.3 mg kg^{-1}), AFeOX (30.5 mg kg^{-1}) and RES (279.7 mg kg^{-1}) fractions was observed in groundnut-potato-bajra (fodder) cropping system as compared to groundnut-toria+gobhi sarson (2.21, 17.1, 30.4 and 260.1 mg kg^{-1}respectively) cropping system. Similar results were observed by Agbenin and Henningsen (2004) reported that application of FYM increased AMOR-Mn, but decreased CRYST-Mn, probably by the inhibition of Mn crystallization.

Interactions among Micronutrient Fractions

Results for the relationships between different fractions of Zn, Cu, Fe and Mn have been presented in Table 6. Significant and positive correlation was observed between WSEX-Zn fraction and SpAd, MnOX AFeOX, CFeOX and OM fractions of Zn. Similarly, SpAd-Zn fraction was significantly and positively correlated with MnOX, AFeOX, CFeOX, OM and total fractions of Zn, whereas the AFeOX, CFeOX, OM and total fractions of Zn showed positive and significant correlations with MnOX-Zn fraction. Significant and positive correlations were observed between CFeOX-Zn fraction and OM fraction of Zn. Similarly, significant and positive correlations were also observed between OM-Zn and total fraction of Zn. The SpAd-Cu fraction was significantly and positively correlated with MnOX-Cu fraction. Significant and positive correlation was observed between MnOX-Cu fraction and RES and total fractions of Cu. Whereas, total-Fe fraction showed a significant and positive correlation with RES-Fe fraction. The WSEX-Mn fraction was significantly correlated with MnOX fraction of Mn. On the other hand, AFeOX-Mn fraction was significantly correlated with CFeOX-Mn fraction.

The present studies indicate that levels of Zn in WSEX, SpAd, MnOX, CFeOX, OM, RES and total fractions were significantly higher under groundnut-potato-bajra (fodder) cropping system. The WSEX, AFeOX, CFeOX and OM fractions of Cu were significantly higher in soil under maize-potato-mungbean cropping system as compared to other maize based cropping systems. The WSEX and SpAd fractions of Fe and Mn were significantly higher in soil under rice-wheat cropping system as compared to maize-wheat and cotton-wheat cropping systems. Higher levels of Fe and Mn in these fractions may be due to reduced condition during rice crop season. Significantly higher levels of Fe in WSEX, SpAd and OM fractions were observed under maize-potato-mungbean cropping system as compared to other maize based cropping systems.

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Effect of Irrigation and Nitrogen Management on Performance of Winter Sunflower (*Helianthus annvs* L.)

Satwinder Kaur, S.S. Kukal and G.S. Hira

Department of Soil Science, Punjab Agricultural University, Ludhiana-141004, Punjab, India
E-mail: satwinderjit.kaur@yahoo.com

Abstract: Irrigation scheduling and nitrogen fertilization has a great influence on sunflower (*Helianthus annus* L.) growth and yield. A field study was conducted to monitor the effects of irrigation regimes, nitrogen application rates and methods in a sandy loam soil. The treatments during first year included four irrigations schedules in main plots viz. i) irrigation water amount minus rain amount to cumulative pan evaporation ratio (IW/CPE) of 0.6 throughout the crop growth period ($I_{0.6}$), ii) IW/CPE of 0.9 throughout ($I_{0.9}$), iii) IW/CPE of 1.2 throughout ($I_{1.2}$) and iv) irrigation was withheld until 50% anthesis and thereafter applied at IW/CPE of 1.2 ($I_{1.2F}$). Nitrogen was applied @ 30 (N_{30}), 60 (N_{60}) and 90 (N_{90}) kg ha^{-1} as the sub plot treatments at the time of sowing. The treatments during the second year were similar to those during first year except that treatment $I_{0.6}$ was modified to $I_{0.6/1.2}$ due to very low rains during early crop season. Irrigation was applied on the basis of IW/CPE of 0.6 till flowering and subsequently on the basis of IW/CPE ratio of 1.2 ($I_{0.6/1.2}$). In addition, the nitrogen during second year was applied before PSI and at the time of sowing (AS) as per the treatments. The experiment was laid out in factorial randomized block design with three replications. The plant parameters (like plant height, stem girth etc.) were significantly affected by irrigation, applied nitrogen and method of N application. The advantage of PSI for increasing grain yield was highest when irrigation was limited or withheld during vegetative stage i.e. 50% anthesis stage.

Key Words: Sunflower, Irrigation Regime, Nitrogen Rates, Growth Parameters, Yield Components

Soil moisture plays an important role in ripening and synchronous maturity of sunflower heads as the crops exhibit hydro-positive features (Compos, 1972; Yadav and Pal, 1973). Water stress during the early growth stages limits the leaf area index, which is closely correlated with the final yield (Connor and Jones, 1985). Nitrogen plays an important role in improving crop growth and realizing production potential of sunflower. Nitrogen application along with pre-sowing irrigation (PSI) has been shown to be the most appropriate method under different irrigation and nitrogen levels for wheat crop (Sidhu *et al.*, 1994). Nitrogen and water interact with each other and improve the efficiency of each other and to a certain extent can substitute for each other. Nitrogen and water interaction, however, depends upon amount of water supply and its distribution pattern in cropping season. A given amount of rain would give optimum yield in dry land wheat only if it occurs in a specific pattern, and yields could be below normal if the distribution pattern is erratic (Sandhu *et al.*, 1992). Hence under a given water supply, the frequency of irrigation is likely to change the behavior of applied N for evolving a strategy to obtain optimum crop yields for different water supplies. Thus a study was carried out to determine the effect of scheduling irrigation, nitrogen rates and method of N application on growth, yield and yield contributing components of winter sown sunflower.

MATERIAL AND METHODS

Field experiments were conducted at the Research Farm of Punjab Agricultural University, Ludhiana (30°54´ N latitude, 75° 48´ E longitude, at 247 m above the mean sea level) for two years. The soil was fine sandy loam, hypothermic mixed calcareous, typic ustochrept (Table1). The total rainfall during the growth season was 132.1 mm first year and 86.8 mm during second year of study. The cumulative pan evaporation during the corresponding years was 637.5 and 631.7 mm, respectively. The treatments during first year included four irrigation schedules, viz. (i) irrigation water amount minus rain amount to cumulative pan evaporation (IW/CPE) of 0.6 throughout the crop growth period ($I_{0.6}$), (ii) IW/CPE of 0.9 throughout ($I_{0.9}$), (iii) IW/CPE of 1.2 throughout ($I_{1.2}$) and (iv) irrigation was withheld until 50% anthesis and thereafter applied at IW/CPE of 1.2 ($I_{1.2F}$). Nitrogen was applied @ 30 (N_{30}), 60 (N_{60}) and 90 (N_{90}) kg ha^{-1} as the sub-plot treatments at the time of sowing. The treatments during the second year were similar to those during first year except that treatment $I_{0.6}$ was modified to $I_{0.6/1.2}$ due to very low rains during early crop season. Irrigation was applied according to IW/CPE of 0.6 till flowering stage and subsequently with a ratio of 1.2 ($I_{0.6/1.2}$). In addition, the nitrogen during second year was applied before PSI and at the time of sowing (AS) at the earlier mentioned rates. The experiment was laid out in factorial randomized block design with three replications.

The field was pre- irrigated with 7.5 cm of irrigation and ploughed twice with a tractor drawn cultivator, followed by planking with a wooden plank to prepare it for sowing at field capacity moisture content. In each year sunflower crop

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Table 1. Basic characteristics of the study soils

Soil depth (cm)	Sand	Silt	Clay	pH	EC	Organic carbon	Available N
		(%)			$dS\ m^{-1}$	(%)	(kg ha^{-1})
0-15	81.0	9.9	9.1	8.1	0.29	0.30	142
15-30	79.4	10.3	10.4	8.0	0.27	0.21	134
30-60	78.2	11.3	10.5	7.9	0.26	0.20	90
60-90	77.0	10.6	12.4	7.7	0.25	0.17	52
90-120	75.9	10.9	13.4	7.8	0.21	0.10	46
120-150	75.0	9.8	15.2	7.9	0.20	0.08	50
150-180	74.8	9.4	15.8	7.8	0.20	0.08	49

(cv. Jawalamukhi) was sown during the first fortnight of December on the southern side of the east-west ridges in order to provide better temperature for germination. The nitrogen as urea was applied as per the treatments, whereas phosphorous @ 60 kg P_2O_5 ha^{-1} and potash @ 30 kg K_2O ha^{-1} were applied at the time of field preparation. A common irrigation after sowing was applied before the start of differential irrigation as per treatment.

Plant parameters viz. plant height, stem girth were measured at 50% flowering stage during both the years. Three plants were randomly selected from each plot. Plant height was measured and average value of 10 plants was obtained in each treatment. Similarly, stem girth of three randomly selected plants was measured as circumference at the point of maximum thickness of the stem. At harvest, head diameter, 1000-seed weight, achene and stover yield were recorded in each treatment. For quality attributes oil content was determined with Nuclear Magnetic Resonance Spectroscope. The data so obtained were analyzed statistically as factorial experiment in randomized block design treatments compared with Least Square Difference (LSD) at 5% level of significance (Steer and Torrie, 1960).

RESULTS AND DISCUSSION

Plant Height

Plant height increased with the level of irrigation. During year-I, maximum plant height (202 cm) was significantly higher in most frequent irrigated regimes ($I_{1.2}$) than other less frequently irrigated treatments (Table 2). Similarly in year-II, maximum plant height (181 cm) was also significantly higher in $I_{1.2}$ irrigation regime. Under limited water supplies ($I_{1.2F}$) the plant height was significantly lower than in other regimes . Irrigation improved the plant height significantly (Sharma 1994; Venkanna *et al.*, 1994; Pal and Yadav, 1974; Khaliq and Cheema; 2005). Plant height also increased with increase in the nitrogen level up to 90 kg ha^{-1}. However, the increase was significant till 60 kg ha^{-1} and heights obtained at N_{60} and N_{90} were found to be at par during both the years of study.

Table 2. Plant height (cm) of winter sunflower in relation to differential irrigation regimes and N application rates

Irrigation regime	N rates(kg ha^{-1})			
	30	60	90	Mean
Year-I				
IW/CPE 0.6	178	189	196	188
IW/CPE 0.9	189	197	202	196
IW/CPE 1.2	198	203	206	202
IW/CPE 1.2 F	179	184	179	181
Mean	186	193	196	
Year-II				
IW/CPE 0.6/1.2F	162	171	168	167
IW/CPE 0.9	172	179	180	177
IW/CPE 1.2	176	183	185	181
IW/CPE 1.2 F	132	139	143	138
Mean	160	168	169	
LSD(0.05)	Year-I	Year-II		
Irrigation regime(I)	4.69	3.32		
N rate(N)	4.06	2.88		
I x N	NS	NS		

The PSI method increased plant height significantly over AS method of N application. The highest plant height (184 and 178 cm) was obtained with more frequent irrigation ($I_{1.2}$) with PSI and AS method of N application respectively (Table 3). Increase of 4, 8 and 8 cm was recorded at 30, 60, 90 kg ha^{-1}. Similarly at $I_{0.6/1.2F}$, $I_{0.9}$, $I_{1.2}$ and $I_{1.2F}$, the increase in PSI over AS method, observed was 10, 7, 6 and 9 cm, respectively.

Stem Girth

Stem girth increased with increase in irrigation level. Maximum girth (11.1 cm) obtained at $I_{1.2}$ irrigation regime was significantly higher than the girths obtained under $I_{0.6}$, $I_{0.9}$ and $I_{1.2F}$ during year-I (Table 4). Stem girth recorded at $I_{0.6/1.2F}$, $I_{0.9}$, $I_{1.2}$ irrigation regimes were statistically similar. But these were significantly higher than the girth obtained under $I_{1.2F}$ (limited water supply) regime. Increase in nitrogen level

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Table 3. Plant height (cm) of winter sunflower in relation to differential irrigation regimes and N application rates applied at sowing and at PSI during year-II

Irrigation regime	N rates (kg ha^{-1})			
	30	60	90	Mean
At PSI				
IW/CPE 0.6/1.2 F	162	175	178	173
IW/CPE 0.9	173	183	184	180
IW/CPE 1.2	178	186	187	184
IW/CPE 1.2 F	135	144	147	142
Mean	162	172	173	
At Sowing				
IW/CPE 0.6/1.2F	161	166	163	163
IW/CPE 0.9	170	174	176	173
IW/CPE 1.2	173	180	182	178
IW/CPE 1.2 F	128	134	138	133
Mean	158	164	165	
LSD(0.05)				
Method of N application(M)	2.35			
Irrigation (I) x M	NS			
N rate(N) x M	NS			
I x N x M	NS			

increased the stem girth. During the first year of study, mean girths at 30, 60, and 90 kg ha^{-1} were 10.1, 10.5 and 10.9 cm, respectively, which were significantly different from each other. During the second year of study, stem girth increased up to 90 kg ha^{-1}, but this increase was significant till 60 kg ha^{-1}. The thickest stems were recorded under most frequent irrigation regime during both years. Application of nitrogen fertilizer with limited irrigation regime did not increase the girth. The reduction in stem thickness under reduced frequency of irrigation in sunflower has been reported by Kakar and Soomro (2001). Steer and Hocking (1984) reported that the stem girth was positively influenced by N application in sunflower. Ahmad *et al.*, (1992) also reported increase in stem girth of sunflower as a consequence of nitrogen application.

Significantly higher stem girths were obtained with PSI method of N application than AS method in $I_{0.6/1.2F}$, $I_{0.9}$ and $I_{1.2F}$ irrigation regimes where less frequent and no irrigation was applied up to 50% anthesis stage (Table 5). Under most frequent ($I_{1.2}$) regimes, girths recorded with both methods of N applications were at par.

Head Diameter

Head diameter at harvesting was significantly (P=0.05) affected by amount of irrigation. Maximum head diameter (19.2 cm) was recorded under frequent irrigation regimes $I_{1.2}$ which is significantly higher than the head diameter obtained under other three irrigation regimes (Table 6).

Table 4. Stem girth (cm) of winter sunflower in relation to differential irrigation regimes and N application rates

Irrigation regime	N rates (kg ha^{-1})			
	30	60	90	Mean
Year-I				
IW/CPE 0.6	9.9	10.2	10.5	10.2
IW/CPE 0.9	10.3	10.6	10.8	10.6
IW/CPE 1.2	10.5	10.9	11.8	11.1
IW/CPE 1.2 F	9.8	10.2	10.4	10.1
Mean	10.1	10.5	10.9	
Year-II				
IW/CPE 0.6/1.2F	7.8	8.3	8.6	8.2
IW/CPE 0.9	8.3	8.4	8.9	8.5
IW/CPE 1.2	8.0	8.6	8.8	8.5
IW/CPE 1.2 F	7.1	7.6	7.7	7.5
Mean	7.8	8.2	8.5	
LSD(0.05)	Year-I	Year-II		
Irrigation regime(I)	0.27	0.41		
N rate(N)	0.23	0.35		
I x N	NS	NS		

Table 5. Stem girth (cm) of winter sunflower in relation to differential irrigation regimes and N application rates applied at sowing and at PSI during year-II

Irrigation regime	N rates(kg ha^{-1})			
	30	60	90	Mean
At PSI				
IW/CPE 0.6/1.2 F	7.8	8.5	8.9	8.4
IW/CPE 0.9	8.4	8.6	9.3	8.8
IW/CPE 1.2	7.8	8.8	8.9	8.5
IW/CPE 1.2 F	7.8	8.1	8.2	8.1
Mean	8.0	8.5	8.8	
At Sowing				
IW/CPE 0.6/1.2F	7.9	8.1	8.2	8.1
IW/CPE 0.9	8.1	8.2	8.5	8.3
IW/CPE 1.2	8.2	8.5	8.7	8.4
IW/CPE 1.2 F	6.4	7.1	7.2	6.9
Mean	7.6	8.0	8.2	
LSD(0.05)				
Method of N application(M)	0.29			
Irrigation (I) x M	NS			
N rate(N) x M	NS			
I x N x M	NS			

During year II mean head diameter obtained under $I_{0.6/1.2F}$, $I_{0.9}$ and $I_{1.2}$ regimes were statistically found to be at par. But the irrigation regime at which least amount of water was supplied ($I_{1.2F}$) recrded statistically lower head diameter. Chaniara *et al.* (1989) and Akhtar *et al.* (1993), quoted that head diameter in sunflower is reduced under limited water

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supplies. Cox and Jolliff (1986) and Kumar *et al.* (1992) reported an increase in head diameter with increasing irrigation levels. Application of 90 kg ha^{-1} N at all levels of irrigation produced larger heads during both the years as compared with N application at 30 kg ha^{-1}and 60 kg ha^{-1}.Irrigation x Nitrogen interactions were found to be significant. The increase in head diameter in response to N application in the present study confirms the findings of El-Sayed *et al.* (1988) who found that nitrogen increased head diameter of sunflower.

PSI method (15.9 cm) increased the head diameter significantly over AS method (15.3 cm). At lower level of N (30 kg ha^{-1}) same head diameter (14.3 cm) was obtained with both methods of N application. But at higher levels of N (60 kg ha^{-1} & 90 kg ha^{-1}), the head diameter increased with PSI over AS method. Beneficial effects of N on head diameter have also been observed by Chaniara *et al.*, (1989) and Bindra and Kharwara (1992).

Table 6. Head diameter (cm) of winter sunflower in relation to differential irrigation regimes and N application rates

Irrigation regime	N rates(kg ha^{-1})			
	30	60	90	Mean
Year-I				
IW/CPE 0.6	16.9	17.1	18.2	17.4
IW/CPE 0.9	17.6	18.0	18.6	18.1
IW/CPE 1.2	18.7	19.3	19.5	19.2
IW/CPE 1.2 F	17.4	18.1	18.8	18.1
Mean	17.7	18.1	18.8	
Year-II				
IW/CPE 0.6/1.2F	14.7	15.8	17.4	16.0
IW/CPE 0.9	14.8	16.5	17.6	16.3
IW/CPE 1.2	14.3	16.4	18.0	16.2
IW/CPE 1.2 F	13.3	14.1	14.5	14.0
Mean	14.3	15.7	16.9	
LSD(0.05)	Year-I	Year-II		
Irrigation regime(I)	0.93	0.55		
N rate(N)	0.80	0.48		
I x N	NS	0.95		

Seed weight

The 1000-seed weight is commonly a determinant of sunflower yield. During year I, the 1000-seed weights obtained under $I_{0.9}$, $I_{1.2}$ and $I_{1.2F}$ were statistically at par with each other. Significantly lower 1000-seed weight was recorded under $I_{0.6}$ irrigation regime. During year II, 1000-seed weight was not affected significantly with differential irrigation. Nitrogen application had a significant effect on seed weight. The highest mean 1000-seed weight (63.0 and 56.9 g) was obtained with 90 kg N ha^{-1}. The increase in seed weight with increase in N application rate was significant till 60 kg ha^{-1}during year I, and till 90 kg ha^{-1} during year II. Increasing N rates produced sunflower plants with higher seed weight (Mahal *et al.*, 1998).

Table 7. Head diameter (cm) of winter sunflower in relation to differential irrigation regimes and N application rates applied at sowing and at PSI during year-II

Irrigation regime	N rates(kg ha^{-1})			
	30	60	90	Mean
At PSI				
IW/CPE 0.6/1.2 F	15.0	16.5	18.5	16.7
IW/CPE 0.9	14.3	16.9	18.0	16.4
IW/CPE 1.2	14.2	16.1	18.1	16.1
IW/CPE 1.2 F	13.5	14.6	15.1	14.4
Mean	14.3	16.0	17.4	
At Sowing				
IW/CPE 0.6/1.2F	14.3	15.0	16.2	15.2
IW/CPE 0.9	15.2	16.0	17.2	16.1
IW/CPE 1.2	14.4	16.6	17.9	16.3
IW/CPE 1.2 F	13.1	13.6	13.9	13.5
Mean	14.3	15.3	16.3	
LSD(0.05)				
Method of N application(M)	0.39			
Irrigation (I) x M	NS			
N rate(N) x M	NS			
I x N x M	NS			

Table 8. The 1000-seed weight (g) of winter sunflower in relation to differential irrigation regimes and N application rates

Irrigation regime	N rates(kg ha^{-1})			
	30	60	90	Mean
Year-I				
IW/CPE 0.6	54.1	60.6	61.5	58.7
IW/CPE 0.9	58.9	61.5	62.4	60.9
IW/CPE 1.2	61.3	62.5	63.0	62.3
IW/CPE 1.2 F	62.2	64.3	64.9	63.8
Mean	59.1	62.2	63.0	
Year-II				
IW/CPE 0.6/1.2F	50.9	53.8	56.8	53.9
IW/CPE 0.9	49.8	51.4	54.5	51.9
IW/CPE 1.2	48.7	53.5	56.9	53.0
IW/CPE 1.2 F	49.8	53.2	59.5	54.2
Mean	49.8	53.0	56.9	
LSD(0.05)	Year-I	Year-II		
Irrigation regime(I)	3.5	NS		
N rate(N)	3.0	1.8		
I x N	NS	NS		

Grain Yield

Response of sunflower grain yield to irrigation was significant at 5% level of significance. During year I, significantly higher yield (3.16 t ha^{-1}) was obtained in most frequently irrigated regime ($I_{1.2}$) than other less frequently

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irrigated regimes (Table 9). Grain yield did not differ among other irrigation treatments including $I_{1.2F}$, where irrigation was withheld till 50% anthesis stage. The grain yield increased considerably with increase in N rate from 30 to 60 kg ha^{-1}. With further increase in N rate, yield did not increase significantly. During year II, highest grain yield (2.65 t ha^{-1}) was observed in $I_{1.2}$ irrigation regime but was significantly at par with that in $I_{0.9}$ regime. In $I_{1.2F}$ irrigation regime, grain yield was significantly lower than in other regimes. This may be attributed to the low rainfall during early growth period (86.6 mm) as compared to year I (132.1 mm). Under frequent irrigation regime, the favorable soil water status helped in increasing plant height, which could have provided more photosynthetic surface and increased yield. During year I, withholding irrigation until flowering in limited water supply regime ($I_{1.2F}$) reduced plant height as compared to $I_{0.9}$, but the yields were statistically similar in both the regimes. Early season water stress resulted in shorter plants but did not reduce the yield (Unger 1982). Grain yield increased significantly with increase in nitrogen application rate till 90 kg ha^{-1}. Nitrogen increased the plant height, stem girth, head diameter and leaf area index in the presence of adequate moisture. This may be due to the rapid cell division and elongation, as the optimum water supply has the promoting effects on most of the physiological process (Patel and Singh, 1980).

Significantly higher grain yields were obtained with PSI method than AS method of N application in $I_{0.6/1.2F}$ and $I_{1.2F}$ regimes where no or limited irrigation was given up to 50% anthesis stage (Table 10). The yields obtained under $I_{0.9}$ with both methods of N application were at par. The PSI method of N application increased the grain yield significantly over AS method at higher levels of nitrogen i.e. N_{60} and N_{90}. Interactive effects of irrigation, nitrogen and method of N application were observed. Significantly higher grain yield with N application method could be due to the enhanced plant growth during the crop season, significant increase in leaf area index and better development of roots. Chaudhary and Prihar (1974) and Sharma and Chaudhary (1983) also reported the advantage of placing fertilizer N deep in soil on water uptake and crop yield.

Oil yield

Method of N application plays a great role in improving the oil yield. The oil yield increased significantly with increase in irrigation level and nitrogen rates. Under limited irrigation regime ($I_{0.6/1.2F}$ and $I_{1.2F}$), significantly higher yields (1.23 and 1.02 t ha^{-1}) were obtained with PSI method than AS method (1.14 and 0.90 t ha^{-1}, respectively), whereas similar yields were obtained under $I_{0.9}$ regime with both the methods of N application (Table 10). The increase in oil yield at higher N level and with PSI than AS method could be attributed to the increase in grain yield at higher levels of N and with application of N before pre-sowing irrigation. Oil yields are highly influenced by grain yields rather than oil content.

Table 8. Grain yield (t ha^{-1}) of winter sunflower in relation to differential irrigation regimes and N application rates

Irrigation regime	N rates(kg ha^{-1})			
	30	60	90	Mean
Year-I				
IW/CPE 0.6	2.25	2.83	2.97	2.68
IW/CPE 0.9	2.59	2.90	2.93	2.81
IW/CPE 1.2	2.94	3.28	3.26	3.16
IW/CPE 1.2 F	2.46	2.91	3.07	2.81
Mean	2.56	2.98	3.06	
Year-II				
IW/CPE 0.6/1.2F	2.38	2.50	2.60	2.50
IW/CPE 0.9	2.29	2.80	2.82	2.64
IW/CPE 1.2	2.61	2.63	2.70	2.65
IW/CPE 1.2 F	1.86	1.90	2.25	2.00
Mean	2.28	2.46	2.60	
LSD(0.05)	Year-I	Year-II		
Irrigation regime(I)	0.16	0.11		
N rate(N)	0.14	0.09		
I x N	NS	NS		

Table 9. Grain yield (t ha^{-1}) of winter sunflower in relation to differential irrigation regimes and N application rates applied at sowing and at PSI during year-II

Irrigation regime	N rates(kg ha^{-1})			
	30	60	90	Mean
At PSI				
IW/CPE 0.6/1.2 F	2.16	2.80	3.15	2.70
IW/CPE 0.9	2.42	2.56	3.01	2.66
IW/CPE 1.2	2.10	2.54	2.91	2.52
IW/CPE 1.2 F	1.78	2.33	2.58	2.23
Mean	2.11	2.56	2.91	
At Sowing				
IW/CPE 0.6/1.2F	2.38	2.50	2.60	2.50
IW/CPE 0.9	2.29	2.80	2.82	2.64
IW/CPE 1.2	2.61	2.63	2.70	2.65
IW/CPE 1.2 F	1.86	1.90	2.2	2.00
Mean	2.28	2.46	2.60	
LSD(0.05)				
Method of N application(M)	0.07			
Irrigation (I) x M	0.15			
N rate(N) x M	0.14			
I x N x M	0.26			

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Table 10. Oil yield (t ha^{-1}) of winter sunflower in relation to differential irrigation regimes and N application rates applied at sowing and at PSI during year-II

Irrigation regime	N rates(kg ha^{-1})			
	30	60	90	Mean
At PSI				
IW/CPE 0.6/1.2 F	9.78	1.29	1.42	1.23
IW/CPE 0.9	1.13	1.21	1.38	1.24
IW/CPE 1.2	9.62	1.20	1.32	1.16
IW/CPE 1.2 F	8.27	1.06	1.17	1.02
Mean	9.73	1.19	1.32	
At Sowing				
IW/CPE 0.6/1.2F	1.08	1.14	1.21	1.14
IW/CPE 0.9	1.05	1.29	1.31	1.21
IW/CPE 1.2	1.21	1.22	1.24	1.22
IW/CPE 1.2 F	0.85	0.86	1.01	0.91
Mean	1.05	1.13	1.19	1.12
LSD(0.05)				
Method of N				
application(M)	0.23			
Irrigation (I) x M	0.47			
N rate(N) x M	0.41			
I x N x M	0.81			

The study shows that crop growth parameters (plant height, stem girth) and yield attributes like head diameter were significantly influenced by levels of irrigation, nitrogen rates and methods of N application. The advantage of PSI for increasing grain yield was maximum when irrigation was limited or withheld during vegetative stage i.e. 50% anthesis stage.

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Direct Plant Regeneration from Spindle Leaf Roll Explants in Sugarcane

Pallavi Mittal[1], Ruma Devi[2] and S.S. Gosal[3]

[1]*ITS Paramedical College Muradnagar*
[2]*Farm Advisory Service Scheme, Gurdaspur*
[3]*Directorate of Research, Punjab Agricultural University, Ludhiana, India*
E-mail: mittalpallavi29@gmail.com

Abstract: A high frequency single step and a simple method of direct plant regeneration has been developed for two varieties of sugarcane viz., Co J 83 and Co J 88. Spindle leaf roll explants were excised from field grown plants and cultured on MS media supplemented with different concentrations and combinations of auxins (NAA and IBA) and cytokinins (BAP and kinetin). The frequency of plant regeneration and number of shoots per explant was influenced by the variety and concentrations of growth regulators added to the media. The maximum per cent plant regeneration was recorded in Co J 83 (81.63) followed by Co J 88 (76.66). Among the different media compositions, MS media supplemented with NAA 5.0 mg l^{-1} and kinetin 0.5 mg l^{-1} was the best media composition for the direct plant regeneration from spindle leaf roll explants in sugarcane. With either decrease or increase from the optimum level, a significant decline in percent plant regeneration as well as number of shoots per explant was recorded. Moreover, when spindle leaves were cultured on the NAA (5.0 mg l^{-1}) rich media plantlets were regenerated. All the shoots developed on this media regenerated roots and were subsequently transferred to poly bags containing FYM: sand:soil in the ratio of 1:1:1 and kept in glass house. This system can be exploited for genetic transformation experiments in sugarcane and is as easy as leaf disc method in dicots for genetic transformation experiments in sugarcane.

Key Words: Direct Regeneration, Sugarcane, Growth Hormones, Organogenesis, Tissue Culture.

Sugarcane (*Saccharum officinarum* L. 2n= 80 to 205) is one of the oldest sugar crop known to man. India has been the largest producer of sugar in the world, running neck to neck with Brazil, which sometimes excels India. The Indian sugarcane and sugar industry have a unique intrinsic and symbiotic relationship with the rural masses and contribute around 2 per cent to the National Gross Domestic Product (GDP). Unlike other crops, sugarcane has unique agro-industrial potential. It provides useful raw materials to over 25 industries to produce sugar, jaggery and khandsari and a range of agro-industrial co-products e.g. alcohol, paper, variety of chemicals, cattle feed and electricity etc. It is one of the most studied higher plants because of its importance as a crop species, and several advantages for genetic, molecular and physiological studies. High frequency plant regeneration is a pre-requisite for the development of transgenic lines. Sustainability of the micropropagation technique depends upon maintenance of the genetic fidelity of the regenerates.

Good amount of work on tissue culture has been done in sugarcane covering various aspects ranging from callus induction, somatic embryogenesis, regeneration of shoots and shoot tip culture (Ahloowalia and Maretzki, 1983; Ho and Vasil, 1983; Liu, 1993, Fitch and Moore, 1993). In most of these studies, regeneration frequencies from the calli were reported to be low and chances of somaclonal variation is very high owing to the genetic instability of callus cultures (Bara and Nickell, 1969; Larkin, 1982 and Liu, 1993). Reports are scarce on direct shoot regeneration in monocots including sugarcane. Direct regeneration from explants without an interveining callus phase has several advantages, including production of true to type progenies. *In vitro* regeneration of shoots from different explants of sugarcane has been the main pursuit of many studies but in most of the studies regeneration has been through callus (Heinz *et al.*, 1997; Lal, 2003; Navdeep *et al.* 2004 and Raza *et al.* 2012). Callusing results in either epigenetic or genetic changes which are heritable and are also called as somaclonal variations. Somaclonal variation can pose a serious threat to the genomic integrity of regenerated plants during the genetic transformation experiments. We hereby report direct regeneration of shoots from the spindle leaf rolls as affected by varieties and plant growth regulators in sugarcane.

MATERIAL AND METHODS

Primary explants i. e. spindles (5-6 cm length and about 1.5 cm diameter) were derived from the healthy, field grown apical stem portions of sugarcane varieties viz., Co J 83 and Co J 88 by removing the outer mature leaves. Spindles were first washed with Teepol™ for 5-10 minutes to remove dirt and debris followed by washing in running tap water for 10-15 minutes to remove the adhered detergent. Subsequently, spindles were surface sterilized with 0.1 %

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(w/v) $HgCl_2$ for 9-10 minutes with gentle agitation and then rinsed thrice with sterile distilled water in the laminar air flow cabinet. The nodal portions of the spindles were discarded and outer 2 or 3 leaf whorls were removed using a sharp scalpel blade. The innermost leaf whorls were cut obliquely into about 1.0 cm pieces which were wounded at 2-3 places and cultured on MS medium supplemented with different combinations and concentrations of auxins and cytokinins was used. Different media compositions i.e. D_1-D_{11} (Table 1) were used for direct plant regeneration. Cultures were incubated at 25±2°C in diffused light for 10-15 days and then shifted to 16/8 hours, light/dark photoperiod. To prevent microbial decontamination all decontamination procedures and aseptic manipulations were performed in a laminar flow hood (Kreider, 1968). Per cent plant regeneration was calculated as the number of leaf rolls showing plant regeneration over total number of leaf rolls cultured per treatment. Statistical analysis was done according to the CPCS package using factorial CRD design (Singh and Cheema, 1985).

Tissue culture regenerated plantlets are usually very fragile and tender and most of these die if directly transferred to the field conditions mainly because of the transplantation shock. Therefore, in order to improve their survival in the field hardening is a very critical step. Regenerated plantlets from spindle leaves having well developed root and shoot system were removed from the test tubes and thoroughly washed under running tap water. Plants were hardened by keeping in open test tubes containing in ½ MS (without sugar and vitamins) in open test tubes under high light intensity for 7-10 days in the incubation room for elongation of roots and hardening of plants. Thus, the process of hardening acclimatized the plantlets for their subsequent transfer to soil. The hardened plantlets were then transferred to the normal field soil with farm-yard manure in polythene bags and kept in the glass house.

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) for experimental design given in Table 2 revealed the significance of varieties (g), hormonal concentrations (h) and their interaction for plant regeneration and number of shoots per explant. This indicated that *in vitro* response of spindle leaf rolls was variety dependent and differed significantly with the kind and concentration of the growth regulators. Organogenic response recorded in leaf rolls of two sugarcane varieties viz., Co J 83 and Co J 88 are presented in Fig. 1. It is clearly evident from the data that direct shoot regeneration was remarkably influenced by type and concentrations of the auxins and cytokinins used and no organogenesis was recorded in the basal MS media i.e., R_0 media. Fig 1 indicated that both the varieties exhibited fairly high direct plantlet regeneration, when spindle explants were cultured on D_1 medium i.e. MS + NAA (5.0 mg l^{-1}) + Kin. (0.5 mg l^{-1}). Maximum plant regeneration was recorded in variety Co J 83 followed by variety Co J 88 i.e. 81.63 and 76.66 per cent, respectively. Further increase in the concentration of NAA i.e. MS + NAA (10.0 mg l^{-1}) + Kin. (0.5 mg l^{-1}), the direct plant regeneration response of variety Co J 83 declined to 75.38 and in variety Co J 88, 67.17 percent, respectively. The replacement of NAA with another auxin i.e. IBA reduced the per cent plant regeneration considerably in both the varieties.

The data from the Fig. 1 also reveal that the replacement of Kin with BAP at same concentration i.e. 0.5 mg l^{-1} reduced per cent shoot regeneration to 74.25 in variety Co J 83 and 64.96 per cent in variety Co J 88 from 81.63 and 76.66 per cent, respectively. Thus, Kin is more effective than BAP for

Table 1. Different concentrations and combinations of auxins (NAA and IBA) and cytokinins (BAP and kinetin) used for the direct plant regeneration in different varieties of sugarcane

Medium code	Basal medium	Kin. (mg l^{-1})	BAP (mg l^{-1})	NAA (mg l^{-1})	IBA (mg l^{-1})
D_0	MS	-	-	-	-
D_1	MS	0.5	-	5.0	-
D_2	MS	0.5	-	10.0	-
D_3	MS	-	0.5	5.0	-
D_4	MS	-	0.5	10.0	-
D_5	MS	0.5	-	-	5.0
D_6	MS	-	0.5	-	5.0
D_7	MS	0.5	0.5	5.0	-
D_8	MS	1.0	-	5.0	-
D_9	MS	1.0	-	10.0	-
D_{10}	MS	-	1.0	5.0	-
D_{11}	MS	5.0	-	0.5	-

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Table 2. Analysis of variance for per cent direct plant regeneration and number of shoots per explants in relation to genotypes and hormonal concentrations in sugarcane

Source	Df	Regeneration (%)	No of shoots
Genotype (g)	3	343.61*	706.90*
Hormone (h)	9	6481.77*	432.34*
Gxh	27	18.95*	26.47*
Error	120	3.35	5.621

* :significant at 5% level of significance

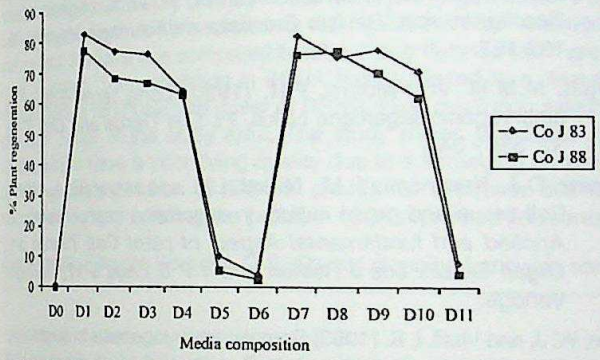


Fig. 1. Effect of media composition on per cent direct plant regeneration from spindle leaf rolls of different varieties of sugarcane

direct shoot regeneration. Further, increase in the concentration of Kin. i.e. up to 5.0 mg l^{-1} was not effective for direct shoot regeneration from spindle leaves. Visual observation indicated that cytokinins at high concentrations increased chlorophyll content and compactness of the tissues. The higher levels of cytokinins might have resulted in chlorophyll development rather than shoot regeneration.

Plate 1 (A-C) shows that when spindle leaves were cultured on the NAA (5.0 mg l-1) rich medium, whole plants (both with shoots and roots) were regenerated without transferring the plantlets to rooting medium (Plate 1D & Plate 2). This system of obtaining direct shoots from the cultured spindle leaves had advantage of being a single step regeneration method which required less time and minimized the chances of somaclonal variations during tissue culture. This system can be exploited just like leaf disc method in dicots. The regeneration capacity was significantly influenced by combination and concentration of auxin and cytokinin (Fitch and Moore, 1993). Similarly, frequency of plant regeneration was reported to vary with the variety (Falco *et al.*, 1996).

The data presented in Fig. 2 represent the number of shoots per spindle leaf roll of the sugarcane. Shoots were often observed after 15-18 days of culture in both the varieties. Shoots were obtained on all tested media compositions except in D_0 which lacked plant growth hormones. The highest average number of shoots i.e.

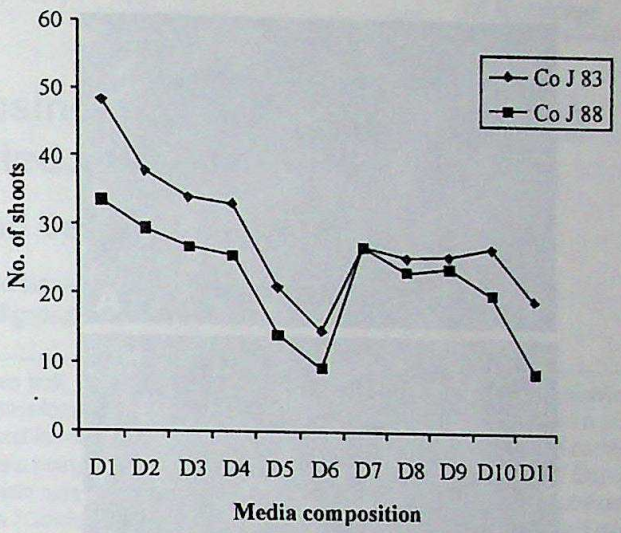


Fig. 2. Effect of media composition on number of shoots from spindle leaf rolls of different varieties of sugarcane.

48.33 per explant was recorded in variety Co J 83 on D_1 media composition in which MS media was supplemented with NAA 5.0 mg l^{-1} and kinetin 0.5 mg l^{-1}. Variety Co J 83 was followed by Co J 88 (33.66 average number of shoots). A decline was recorded in average number of shoots with either increase or decrease from these hormonal concentrations in both the varieties. The genotypic differences in the ability to regenerate shoots were also reported by various workers (Bara and Nickell, 1969 and Kalaw *et al.*, 1977).

Rate of shoot multiplication *in vitro* was studied in two varieties of sugarcane (Table 3). Shoot clumps derived from the spindle leaf rolls were cultured for three cycles of three weeks each on MS media supplemented with IAA 3.0 mg l^{-1} BAP 0.3mg l^{-1} and kinetin 0.3 mg l^{-1} starting with 23 and 25 culture jars of Co J 83 and Co J 88, respectively. It became mandatory to sub-culture after every three weeks of culturing for rapid shoot proliferation as no sub-culture invariably led to depletion of the culture media. The rate of multiplication was calculated on the basis of plants regenerated from single explants through repeated sub-culturing. After five cycles of culturing 4056 and 3124 culture jars were obtained in Co J 83 and Co J 88, respectively. The extent of shoot multiplication ranged between 176.35 percent in Co J 83 to 124.96 per cent in Co J 88. The multiplied plantlets when

Table 3. *In vitro* shoot multiplication of sugarcane genotypes from spindle leaves after three cycles culturing of three weeks each

Genotypes	Number of cultures		
	N 1	N 2	Multiplication rate (%)
Co J 83	23	4056	176.35
Co J 88	25	3124	124.35

N 1: Initial number of jars cultured; N 2: Number of cultured jars after three cycles

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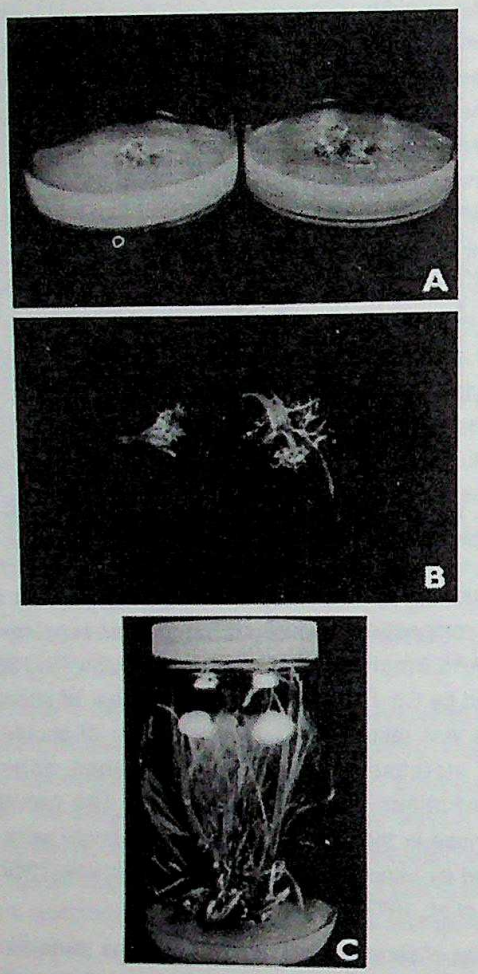


Plate 1.
(A) Cultures showing direct shoot regeneration from spindle leaf roll explants after one week of culturing
(B) A close up view ofdirect shoot regeneration from leafrolls
(C) Cultures showing quick shoot elongation from leafrolls after one month of culturing



Plate 2. Cultures showing rooting from leafrolls after one month of culturing

transferred to soil exhibited good survival rate ranging from 85-90 per cent. This protocol can be efficiently used for large scale multiplication and genetic engineering studies.

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Study of Land-use Compatibility using Remote Sensing and GIS Bhiwandi Surrounding Notified Area (BSNA) Mumbai

Karamjeet Singh and Deepti Singh

Punjab Remote Sensing Centre, Ludhiana-1410 04, Punjab, India
E-mail: Kjeet12@gmail.com

Abstract: Land is the most important natural resource, which comprises soil, water and the associated flora and fauna, thus involving the total ecosystem. Any country in the world is trying to achieve stable development. Spatial planning is trying to organize the human and activity in environment in such a way that stable development would be achieved in various contexts. The present study has been carried out to find the land use compatibility after doing detailed land use analysis using remote sensing and GIS as well as potentials of BSNA, near Mumbai. The population in BSNA has increased at a decadal growth rate of 44% during 1981-1987. This resulted in a haphazard distribution of land use/land cover of BSNA. High resolution satellite data (Quick Bird-61 cms) has been used to prepare the detailed land use/land cover of the study area. The study shows that BSNA is randomly distributed with haphazard growth of urbanization for e.g. Slums which have a poor living quality due to submerging between industries. Large amount of warehouses also generate employment, attracting the population of different places for economic activities. Employment is an important factor which is cause of population concentration and creating the problem of unauthorized residents and slums in this area.

Key Words: Remote Sensing, GIS, Spatial planning Land use compatibility

Land is the most important natural resource, which comprises soil, water and the associated flora and fauna, thus involving the total ecosystem. Knowledge of spatial distribution of land use, land cover is essential for planning and management activities. The term land cover describes type of materials/features present on the surface of earth, e.g., vegetation, rocks, buildings and highways, while the expression land use relates to human activity, i.e., how a land is used such as, for agriculture, residence and industry.

Any country in the world is trying to achieve stable development. Stable development may be defined as "suitable and efficient utilizing from natural, financial and human resources to achieve a desirable consumption pattern and utilizing suitable technical and organizational abilities which provide current and future necessities "(sadough2001).

Spatial planning is trying to organize the human and activity in environment in such a way that stable development would be achieved in various contexts. Spatial Planning is defined as adjusting the relationship between human, land and human activities in the land in order to have a stable utilization from all spatial and human possibilities to improve material and moral situation of society along the time (makhdoum1999).

Geographical Information System is an important tool in development planning for two principal reasons. Firstly, it is oriented to the spatial component of development. This comprises the use of the land for human settlements, the use of land resources as in agriculture and forestry, and the management and protection of the natural environment. Second, GIS is not oriented solely to geographic aspects of planning, but also to its informational contents. It can also provide major help in identifying trouble spots and in suggesting possible actions. Land use mapping using survey methods has been a lengthy and cumbersome procedure which needs to be updated. The use of GIS and Remote Sensing is helpful in time saving and efficient land use mapping.

MATERIAL AND METHODS

Introduction to Study Area

BSNA is Bhiwandi surrounding notified area in Mumbai. Before the emergence of Mumbai, Bhiwandi because of its strategic location, Bhiwandi had been an important trading center. During Mughal rule, Bhiwandi was known as Bhimbari.

Bhiwandi, is located in the east of Sahyadri mountain ranges which belongs to the North Konkan region of Maharashtra in the Konkan coastal lowlands. The average elevation is 24 m above msl. The Bhiwandi Surrounding Notified Area lies between 19° 12' 07" N to 19° 21' 50" N latitude and 72° 59' 48" E to 73° 7' 50" E longitude. It forms a part of the Mumbai Metropolitan Region. (Environment Status Report Bhiwandi, 2004-05).The boundary of BSNA is marked by hills, ridges and forests in the north, east and northwest. The Ulhas River demarcates its southern boundary. Due to natural hard and soft high-rise and low-lying features in its surroundings, Bhiwandi has a saucer

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type of topography. Due to natural water bodies like rivers and creeks located in its vicinity, a major chunk of land of Bhiwandi remains under swampy conditions due to backlash of marine water and subsequent inundation due to the presence of Thane creek, Bassein creek and other minor inlets increasing the landmass.

One of the development potentials of this site is its nearness to District Thane and the metropolis of Mumbai. It is located at 16 kms from Thane and 10 kms from Kalyan. It is linked to Thane and Mumbai through Bombay-Nasik National Highway No.3, Vasai through Kalyan through National Highway No. 222 and Vasai-Diva railway line. Due to its nearness to Mumbai city and good transportation network, the Godowns and warehouses for storage goods for Mumbai market are located here and the town is famous for both handlooms and power looms. These factors have been playing a major role in changing the development scenario of the town. However, the drainage of the area is poor due to its topographical and geological conditions. Agriculture is also poor due to presence of marine water and poor irrigation facilities. The villages in BSNA have been neglected because of poor transportation and communication system.

Demographics

The population in BSNA has increased at a decadal growth rate of 44% during 1981-1987. It has further increase at a higher growth rate of 47.2% during 1991-2001. The growing population of BSNA may be attributed to natural growth, influence of migration, increasing employ ability in the warehousing sector and power loom industries in BSNA and Bhiwandi city.

Table.1 indicates that the population in BNSA has experienced a rising trend between 1981-2001.

Table 1. Decadal growth rate of BSNA

Year	Total Population	Decadal growth rate
1981	79242	-
1991	114349	44.3%
2001	165633	47.2%

The main objectives of study are:

To analyze the land use break down of BSNA and find out the compatibility of different land uses, using the remote sensing and GIS.

Identifying the major constraints and potentials of different land uses of study area adopting GIS techniques.

Availability of high resolution satellite data has provided an opportunity for the detailed study of Bhiwandi Surrounding Notified Area for the year 2008. Georeferenced Quick-Bird data (multispectral) of the year 2008 with spatial resolution of 60 cm was used to interpret the land use/land cover of study the area. The satellite data was procured from National Remote Sensing Agency (NRSA) Hyderabad in digital form. All the ancillary data used with the satellite data was registered with respect satellite image.

After the theoretical framework the georeferenced Quick Bird data of year 2008 having 61cm spatial resolution was used to interpret the land use /land cover of study area. After the field survey and verification of ground truthing the final map of land use and land cover has been prepared with relation to development pattern and layer of structures are also prepared. On the bases of land use map the compatibility of land uses are also analyzed.

The flowchart of entire methodology at various stages is shown in Fig. 1.

For final output, the land use of villages was classified into 19 categories as shown in Table 2.

Table 2. Land use categories

S.No.	Categories
1	Residential
2	Industrial
3	Commercial
4	Mixed-built-up
5	Warehouses
6	Public/semi-public
7	Electric sub stations
8	Elevated service reservoir
9	Water works & Treatment plants
10	Roads
11	New structures
12	Agricultural land
13	Forest
14	Wetland
15	Cultivable but barren land
16	Mining area
17	Brick kilns
18	Open spaces
19	Water bodies (Rivers, creeks, Island lakes, ponds, wells)

RESULTS AND DISCUSSION

Existing Land Use

The existing land use map of BSNA has been prepared on the basis of satellite imageries with 0.61cm spatial and 11bit radiometric resolution. The quick bird satellite imageries of March 02, 2008. are used to obtain land use layers in Arc GIS software.

The detailed land use of BSNA is shown in Table 3. BSNA comprises of 59 constituent villages. The total area of BSNA computed on GIS platform is 144.89 Sq km. BSNA also includes the Census towns which are part of the urban

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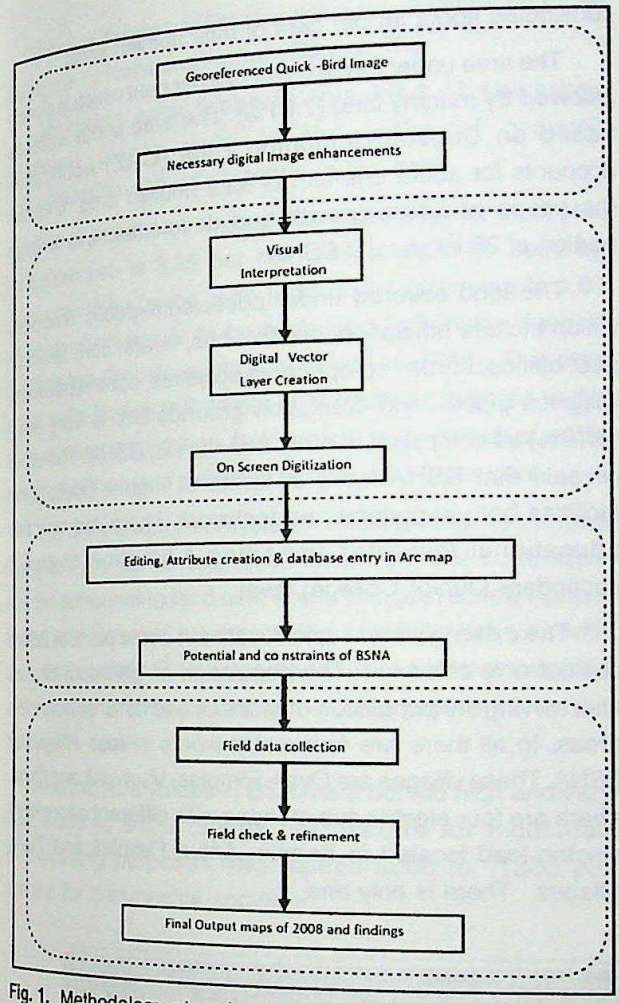


Fig. 1. Methodology at various stages

agglomeration.

It is evident from Table 3 that warehousing is the dominant land use under built up category in BSNA. The area under warehousing is about 5 per cent of total area closely followed by the residential use, which constitutes 3.6% area i.e. 525.68 hectares. Fig. 2 shows that the dominated land use i.e. warehouses or godowns/storage are largely concentrated in southwest portion of the area. The area devoted to elevated service reservoirs is about 0.36 ha. Table 3 shows that area under mixed category which includes residential, commercial and industrial together accounts for about little less than 1 per cent of total BSNA.

The other uses include agricultural use, marshy land, cultivable but barren land and forest etc. The dominated land use category is agricultural use which covers 8454 hectare which comprises about 58 per cent of total BSNA.

Forest land constitutes about 1303 ha which is about 9% of total area. The marshy land covers about 7.6 per cent of total BSNA. It might be attributed to the presence of several creeks, tidal flats, mudflats and bars experiencing backlash under the influence of spring tides and rivers resulting in swampy conditions in adjacent lands. The map shows that there are detached patches of mining area observed in Mankoli and Ovali villages.

The area under mining sites is about 1 per cent of total BSNA. Another interesting feature of BSNA is large chunk of

Table 3. BSNA: Existing land use distribution (2008)

S.No	Land use class	Area (ha)	Percent to total BSNA area
A	Built-up uses		
1	Residential	525.68	3.63
2	Industrial	371.22	2.56
3	Commercial	82.77	0.57
4	Warehousing/godowns	651.12	4.50
5	Mixed	118.08	0.82
6	Public/semi -public	26.94	0.19
7	Electric sub-stations	27.40	0.19
8	Elevated service reservoir	0.36	0.002
9	Water works and treatment plants	36.50	0.25
10	Major roads	75.54	0.52
11	New structures	0.31	0.002
B	Other uses		
1	Agricultural land	8454.15	58.38
2	Forest	1303.76	9.00
3	Marshy land	1101.68	7.61
4	Cultivable but barren land	484.47	3.35
5	Mining brea	155.48	1.07
6	Brick Kilns	128.94	0.89
7	Water bodies (Rivers, inland lakes, ponds, creeks, wells etc)	353.51	2.44
8	Open Spaces and green belt, water supply pipelines and railways	583.90	4.03
C	*Total area*	14489.85	100.00

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cultivable land (3.35 per cent of total area) but is barren. This land could be utilized for development purposes. The remote sensing data also exhibits that brick kilns cover about 128 ha. Water bodies which include inland rivers, lakes, ponds and wells etc. cover 353 ha land which constitutes 2.44 per cent of total area. The open spaces and green belt, water supply pipelines cover about the 4% of the total area. The BSNA land utilization pattern has a diverse composition in terms of total development scenario.

Compatibility of Land Use

The compatibility of the land use is an essential component for assessing the qualitative aspect of land use. The existing land use of the area shows that there are some land uses which are not compatible with the surrounding land uses. Kalher, Purne, and Rahanal villages have a mixing of residential area with warehousing. Some residential areas have mingled with industrial use creating several problems to the residential area.

The foregoing analysis on land use indicates that the BSNA has a distinct land use character as compared to other areas. It has agricultural land, marshy land, cultivable but barren land, quarrying area, forest area, large concentration of godowns/warehouses and industries etc. The maximum use of land in BSNA is for agriculture which constitutes about 58 per cent of total notified area.

The area under forest cover is 9 per cent which is closely followed by marshy land (7.61%). The area under wetlands based on Coastal regulation zone (CRZ) notification accounts for about one-fifth of total notified area. It lowers the scope of future growth and development in a large portion of 35 villages of BSNA.

The land covered under public/semi-public amenities which include educational institutions, health care facilities, post offices, banks, co-operative societies, community halls, religious places and cremation grounds etc. is very small (0.19%) as compared to other activities in BSNA. The study reveals that BSNA lacks in terms of higher educational facilities both in general and technical. There are only five educational institutes imparting education at senior secondary (Junior College) level.

The existing water works located in some parts of BSNA are not only catering to the population of Bhiwandi city but also serving the population of Mumbai and other surrounding areas. In all there are four water works in four villages of BSNA. These villages are Ovali. Pimplas, Vaghivali and Yavai. There are four electric sub stations with different capacity of electric load located in Kambe, Anjur, Pimplas and Yavai villages. There is only one

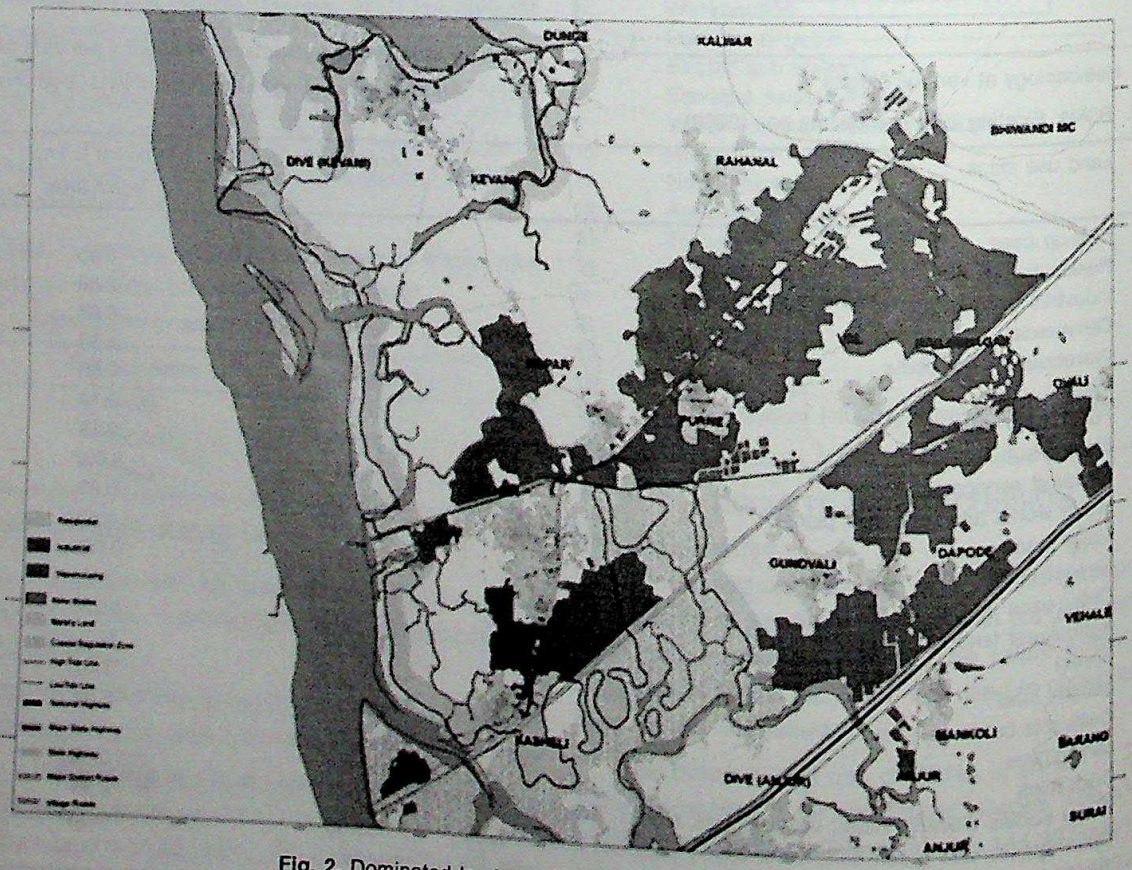


Fig. 2. Dominated land use i.e. warehouses or godowns

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Sewage Treatment Plant in the entire BSNA located on the border of Katai and Khoni villages. The

remaining area lacks in this kind of sewerage treatment plants even in the wake of growing industrialization and urbanization in the area.

The availability of large chunk of land under cultivable but barren use is 3.35 per cent which could be used for development purposes. The land under quarrying is 1.07 per cent which needs to be reclaimed, otherwise it would threaten the delicate ecological cover of BSNA. The area under water bodies is 2.44 per cent whereas the area under open spaces and green belt which also includes water supply pipelines and railways is about 4.03 per cent.

The compatibility analysis of existing land use shows that there are some land uses which are not compatible with the surrounding land use. Three villages namely Kalher, Purne, and Rahanal have a mixing of residential area with the warehousing. Some residential areas have mingled with industrial use creating several problems to the residential areas.

Also the land values in BSNA are not too high and vary from 8000 to 9400 rupees per hectare for industrial/ warehousing purposes and rupees 9000 to 11300 per hectare for commercial activities.

The study brings out that area under wetlands as per CRZ notification is 22.14 sq km which comprises about one-fifth area of coastal villages. The highest area under wetlands is identified in Bharodi village which accounts the about 90.00 per cent of total area of the village followed by 71.78 per cent of total area in Alimghar village. Dive village has about 65 per cent area under wetlands. Kalher village has about 57 per cent area under wetlands. 9 villages out of 35 villages, viz., Kalwar, Kasheli, Kashivali, Kopar, Rahanal, Rajnagar, Sonale, Tambhavali and Vadghar covered under Coastal Regulation Zone do not possess any wetland. It is also notable here that details of CRZ be duly considered while framing the planning proposals for the development plan of the area.

Fig. 3 shows that individual buildings are so congested that it resulted in poor drainage quality of the area.

The results of this study show that different land use analysis objectives exist for different areas in the study area. The relationship between land (soil as an important land parameter) and land use can be used to differentiate such areas. These areas can be spatially depicted through application of GIS techniques. The Bhiwandi area has a mixed land use type comprising of Industrial, agricultural, warehouses and mixed residential area including slum areas.



Fig. 3. Individual buildings of BSNA

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Remote sensing and GIS techniques havebeen found very useful in finding the type of land use even the individual buildings and residential area merged in between the industrial area was well delineated with high resolution satellite data (Quick bird 61 cm).

The BSNA is randomly distributed with haphazard growth of urbanization for e.g. Slums which have a poor living quality due to submerging between industries. If on one side these industries give proper employment to the residents of Bhiwandi, on the other hand these industries pose serious life threatening problems like water pollution and noise pollution in the area.

BSNA has a poor sanitary system due to which flooding is a major serious treat to the area. Residential land use comprises the 5.63 % of the area, which is in the form of small settlement along with the roads, in old gaonthan of villages, and also spread with the warehouses. Due to intense industrial development there is immense concentration of worker class. These worker classes residing in scattered settlement with inappropriate infrastructure facilities.

BSNA is already textile industrial hub and still growing as centre of textile industries. Large amount of warehouses also generate employment, attracting the population of different places for economic activities. Employment is an important factor which is cause of population concentration and creating the problem of unauthorized residents and slums in this area. Some of residential usage are located in low laying area (Pimplas, Pimpalner, Vehale, Sarang, Alimghar, Kalher, Dive (Kevani) etc. have severe problem of flooding during monsoon period.

The overall results shows that the BSNA has a unplanned growth of population mixed with industrial area due to which if on one side it gives resources on the other hand also pose life threatening problems

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Canopy Microclimate and Reproductive Behavior of 'L-49' Guava Plants at Different Spacings

J.S. Brar, H S Dhaliwal[1], J.S. Bal[1] and Som Pal Singh[2]

Regional Station (PAU), Bathinda -151001, Punjab, India.
[1]Department of Horticulture, [2]Department of Agrometeorology,
Punjab Agricultural University, Ludhiana-141004, Punjab, India
E-mail: jsbrar74@rediffmail.com

Abstract : The study on 'canopy microclimate and reproductive behaviour of guava plants at different spacing' was intended to see the changes in canopy microclimate with planting density and its effect on flowering & fruiting behaviour in 'L-49' guava plants. The present investigations revealed that with increase in plant spacing from 6x2m to 6x4m, the interception of radiation was increased significantly during both rainy and winter crop seasons. Similarly, with increase in spacing between plants, the mean canopy temperature was increased while the relative humidity was decreased. The flower bud density during both crop seasons was maximum in plants at widest spacing of 6x5m and least in plants at 6x2m spacing. Similarly, the average fruit setting was also higher at wider and least in closely spaced plants. Mean number of fruits per plant, yield per plant and fruiting density was recorded higher in plants at widest spacing of 6x5m and least in plants at 6x2m spacing. The plant spacing of 6x2m and 6x3m was not encouraging owing to lesser distribution of solar radiations and sub-optimal canopy microclimatic conditions. The plant spacing of 6x5m and 6x4m was found to be better due to maximum absorption of solar radiation and optimum microclimate in the orchard leading to be advantageous for better flowering, fruit set and retention.

Key Words: Canopy microclimate, Flowering and fruiting, Guava, Plant spacing

Guava (*Psidium guajava* L.) is very important tropical as well as subtropical fruit crop of the world and is a potential crop of India. Due to its hardy, prolific bearing, high nutritive value, highly remunerative nature, it surpasses many other fruit crops. Moreover this fruit can be grown satisfactorily even in adverse soil and climatic conditions. At present, guava is fifth major fruit crop in India which occupies an area of 0.17 million ha with an annual production of 1.97 million MT with productivity of 11.1 MT per ha (Anon, 2008). However, the productivity potential per unit area of guava is very low due to traditional system of orcharding with low density plantation. Therefore, the main emphasis should be laid on management of tree canopy in such a way to get higher production of good quality fruits per unit area.

In high density planting system, interception of solar radiations and other microclimatic conditions such as canopy temperature and relative humidity are important aspects which directly or indirectly affect the vegetative growth, yield and quality of guava fruits. In case of temperate fruits extensive study on such aspects has been made but little work has been done on tropical and sub-tropical fruit crops. Guava has a higher proportion of 'shade' to 'sun' leaves and these leaves are found photosynthetically inactive under deeper shade and act as unproductive sink (Singh and Dhaliwal, 2007).Therefore, vegetative growth, fruit yield and quality are functions of light interception and translocation of light energy into chemical energy. Production of good quality fruit is function of absorption of light and light is directly proportional to the yield of fruit trees (Jackson,1980; Palmer,1989). Light interception was more in guava trees planted at wider spacing and decrease significantly with the depth of the canopies irrespective of the planting densities (Singh *et al.*, 2005).Similarly Singh and Dhaliwal (2007) reported that fruit yield and quality of guava fruits decreased with poor light interception at higher planting densities. Therefore, the present investigations were made to study the relationship between canopy microclimate, flowering and fruiting behaviour of guava cv. 'L-49' at different plant spacing.

MATERIAL AND METHODS

The present investigations on "canopy microclimate and reproductive behaviour of 'L-49' guava plants at different spacing" were carried out in the New Orchard, Department of Horticulture, Punjab Agricultural University, Ludhiana during the years 2007 to 2009. The plants of guava cv. 'L-49' were planted in March, 2003 at four spacing levels viz. 6x2 m, 6x3m, 6x4m and 6x5m replicated thrice. The observations on solar radiation interception, canopy temperature and relative humidity were recorded at 15 days interval starting from April 2007 to March 2009 in different parts of tree canopy. The solar radiation measurements were recorded in clear days thrice a day viz. 8.00-10 am, 12.00-2.00 pm and 4.00-6.00 pm by recording the sensor

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output from Pyranometer using a Digital Multi-Volt Meter. The Pyranometer measured the total direct and diffuse solar radiation. Incoming solar radiation measurements (Cal/cm²/min) were recorded at one foot above the canopy and at the centre of the upper, middle and lower parts of the tree by facing Pyranometer upward. The Pyranometer was inverted at a height of one foot above the canopy to measure the amount of reflected short wave radiations. The radiation/ light interception was calculated as the difference between incoming radiations received in each of the three different parts of the tree canopy and was expressed as intercepted radiation at a particular time of observation.

Radiation intercepted in the upper part =

$$\frac{I-(I_1+A)}{I} \times 100 = X\%$$

Radiation intercepted in the middle part =

$$\frac{I-(I_2+A)}{I} \times 100 - X\% = Y\%$$

Radiation intercepted in the lower part =

$$\frac{I-(I_3+A)}{I} \times 100 - (X\%+Y\%) = Z\%$$

Total light intercepted by the tree canopy = X+Y+Z

Where,

I = Incoming solar radiation received one feet above top of the tree canopy.

I_1= Incoming solar radiation received in the upper part of the tree canopy.

I_2= Incoming solar radiation received in the middle part of the tree canopy.

I_3= Incoming solar radiation received in the lower part of the tree canopy

The canopy temperature and relative humidity were also recorded midway in the upper, middle and lower parts of the tree on the day of observations of solar radiations thrice a day i.e. 8.00-10 am, 12.00-2.00 pm and 4.00-6.00 pm. Temperature was measured with the help of Infra-red thermometer (Model AG-42) and relative humidity by using Psychron (Belfort Inst.Company Model No 556) measuring dry and wet bulb temperature and then calculations were made by using psychrometeric tables.

The fruiting characters of both rainy and winter season were recorded from May to July and September to December during the year of 2007 and 2008. The observations were recorded in terms of flower bud density (no of flowers/m shoot) by counting the number of flowers on each shoot and average was worked out, fruit set was worked out by dividing the number of fruits set with total number of flowers, fruit retention was noted with division of number of fruits retained with number of fruits set, fruits numbers were directly counted and yield and yield efficiency was calculated.

RESULTS AND DISCUSSION

Meteorological Observations

Radiation interceptions: The mean total radiation intercepted in rainy season (March- August) by the plants was significantly higher i.e. 71.34 % in plants at wider spacing of 6x4m followed by 69.76 % in 6x5m spaced plants and least in plants at closest (6x2m) spacing (Fig.1). The mean radiation interception during winter crop season was found to be increased with increase in plant spacing upto 6x4m spacing. The mean maximum radiations (66.48%) were intercepted in plants at wider (6x4m) followed by plants at 6x5m spacing (Fig.2).

The radiation intercepted during the winter crop season (September-February), in plants irrespective of planting density was recorded lesser as compared to the rainy crop season i.e. March–August. The radiations were found to increase with increase in plant spacing upto 6x4m spacing and again reduced in widest spacing of 6x5m in both crop seasons. The reduction in radiation interception at closest spacing of 6x2m may be due to vertical orientation of auxiliary shoot and leaves causing less absorption of solar radiations. The plants at 6x4m spacing intercepted highest radiations owing to higher foliage and more horizontal orientation of shoots and leaves. The reduction of solar radiation interception at widest spacing of 6x5m may be due to less dense foliage per unit exposed area to solar radiations as the solar radiation interception is the function of leaf area (Singh *et al.*, 2005). Similarly, higher tree density leads to increased light interception through greater leaf area and more even distribution of light (Palmer *et al.*, 1992). Singh *et al.* (2005) and Singh and Dhaliwal (2007) also found that radiation interception by the guava tree increased with increasing planting distance.

During rainy season high temperature coupled with high humidity leads to profuse vegetative growth, therefore more leaf area absorbing more light. The radiation interception during the period of September – February decreased gradually. The leaf shedding during the cool months of the year reduces the total leaf area of the plants which leads to less light interception in the upper parts of the canopy and it was also observed that during this period there was slight increase in light interception in the middle and lower parts of the canopy. The lesser radiation intercepted during this period may be attributed to loss of foliage, leads to less leaf area index during the winter months. Less radiation intercepted in the upper parts of the plant canopies.

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Canopy temperature: The mean canopy temperature was recorded higher in plants at wider spacing (Fig.1). During the rainy season (March- August) highest mean temperature (27.7°C) was recorded in plants at 6x5m spacing. The mean canopy temperature (24.5°C) was in plants at closest (6x2m) spacing. The average canopy temperature during winter crop season (September-February) was lower (Fig. 2) than rainy crop season. The mean temperature in plants at wider spacing was higher than other spacing levels. The plants at 6x5m spacing showed maximum (22.4°C) temperature in their canopies. The least temperature (20.2°C) was noted in the plants at closer spacing of 6x2m. Higher temperature in plants at wider spacing may be ascribed to the more solar radiation penetration and lesser relative humidity.

The findings of Singh (2003) are also in accordance with the present investigation of the canopy temperature varies significantly with the spacing levels in guava cv. L-49. The mean canopy temperature was significantly higher in widely (6x6m) spaced trees comparison to both 6x5m and 6x4m spaced trees. The maximum temperature was recorded in the upper parts of the trees which follow middle and lower parts during the winter months of the year. Similarly, during the summer months (March to August), the canopy temperature at closest (6x4m) was lower than medium and widest spacing.

Relative humidity: The mean relative humidity was recorded maximum (Fig.1) in plants at closer spacing of 6x2m followed by 6x3m and 6x4m and minimum in plants at widest spacing of 6x5m. During the rainy crop season (March- August) same trend was observed. Likewise, during winter crop season (September- February) the relative humidity (Fig.2) was lower (59.9%) in plants at widest (6x5m) spacing and highest (64.0%) in plants at closest (6x2m) spacing. Similarly, the upper parts of canopy have lower relative humidity (60.2%) than middle and lower parts irrespective of plant spacing.

The decrease in relative humidity with increase in plant spacing may be attributed to the more penetration of solar radiation and more circulation of air leading to decrease the relative humidity. Singh (2003) also recorded the maximum average relative humidity in the trees of guava cv. Sardar planted at closest spacing, which was significantly higher during the months of March to August. Similar trend of increment of average relative humidity with decrease in plant spacing was observed during the other part of the year i.e. September to February. Singh and Singh (2007) also study the influence of pruning height at the relative humidity of the tree canopy and found that in unpruned trees of guava cv. Sardar the relative humidity was maximum and it decreases with decrease of pruning height respectively.

Flowering and Fruiting

Flower bud density (FBD): Plant spacing as well as microclimatic parameters had significant effect on flower bud density of rainy (Fig. 3) and winter season (Fig. 4) crops of guava. The FBD was increased with increase in plant spacing. The FBD was improved with increased solar radiation penetration, increase in temperature, and decrease in relative humidity within the plant canopies. The mean maximum number of flower buds/m shoot during rainy season was observed at widest spacing of 6x5m followed by 6x4m spaced plants. In case of winter season guava, the mean flower bud density was observed maximum (13.94) in widest (6x5m) spacing followed by 7.69 in 6x3m spacing level. The FBD was recorded only 2.25 in plants at closest (6x2m) spacing.

The FBD in winter season was quite less due to over bearing during rainy season i.e. the metabolic reserves required for induction of flowering may be reduced due to heavy flowering in April-May thereby affecting the FBD in the month of August- September for winter season crop. The reduction in FBD with decrease in plant spacing may be attributed to reduced radiant energy received, low temperature especially in closer spacing in case of winter season crop, high relative humidity and moreover reduced substrate level with reduction in shoot growth. Increased radiant energy may be responsible for higher photosynthesis and other physiological aspects causing more distribution of energy for conversion of vegetative to reproductive growth. Similarly, the higher range of temperature (25-28°C) during rainy crop season and 22-23°C during winter crop season seems to be optimum for better flowering. Mean daily temperature of 20°C or below may causes adverse effect on flowering. Similarly, the mean seasonal relative humidity of 49-50% during rainy and 59-60 % during winter crop season was found optimum for better flowering as at high relative humidity the FBD may be reduced due to more vegetative growth. The present results are in confirmation with those of Lal *et al.* (2000), who also found that trees in closer spacing (2x2 m) produced lower number of flower buds as compared to higher spacing (8x8 m). Similarly, Singh (2003) also recorded increase in flower bud density with increase in plant spacing.

Fruit set

The fruit set was significantly affected by different spacing for rainy as well as winter season crops.. During rainy season (Fig.3), the maximum fruit set of 62.70 per cent and 59.58 per cent was recorded in wider spacing of 6x5 m and 6x4 m. The minimum fruit set (49.9 %) was noted in plants at 6x2m spacing. However, in winter season

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crop (Fig. 4), the per cent fruit set was found to be higher than rainy season crop due to quite less number of flowers in winter season. Maximum fruit set was observed in plants at widest spacing of 6x3 m (68.25 %) followed by 65.70 per cent at 6x4m and 6x5m spacing. The least average per cent fruit set (60.14%) was observed at 6x2m spacing. Enhancement of fruit setting during winter crop at all spacing levels might be owing to low FBD during this season. The data shown in winter season crop is in line with Lal *et al.* (2000) who reported lesser fruit set in closer spacing (2x2m) as compared to wider spacing (8x8m). Higher fruit set at wider spacing particularly during rainy season crop may ascribed to the better microclimatic conditions i.e. higher solar radiation interception, optimum temperature and lower relative humidity which may leads to better shedding of pollen grains from the stigma followed by better pollination, fertilization and fruit set. Fruit set during both the seasons was reduced at 6x2m spacing, this may be due to low radiation interception and canopy temperature along with high relative humidity (Fig.1& 2) at this spacing level.

Fruit retention

The fruit retention was not significantly affected by different spacing levels (Fig. 3) during rainy season. However, the mean per cent fruit retention in rainy season crop was maximum (43.93%) in widest (6x5m) spacing and the least (41.06%) was observed in 6x2 m spacing. In winter season as indicated in Fig. 4, the fruit retention at 6x4m spacing was maximum i.e.55.28 per cent which was significantly at par with 54.33 per cent at 6x5m spacing. The retention of winter season fruits was higher than rainy season fruits. This may be due to very low fruit count during winter season, thus higher allocation of nutrients and translocates required for holding of fruits on the plants. Data also revealed that although in rainy season, the retention of fruits did not differ significantly with spacing but in winter season fruit retention was noted higher at wider spacing. This may be ascribed to the lesser competition for photosynthates among the developing fruits and moreover, the microclimatic conditions also found more conducive for fruit retention.

Number of fruits

The number of fruits per tree was significantly affected by plant spacing in rainy season harvest (Fig. 5). Highest number of fruits (535 and 490) was obtained from plant at wider (6x5m & 6x4m) spacing, respectively. Fruits were counted lowest i.e.324 at closest spacing of 6x2m. It is pertinent from Fig. 6 that during winter season bearing of fruits was very sparse particularly in plants at closer spacing levels. At widest spacing of 6x5m the average number of 182 fruits was born in comparison to only 31 fruits per plant at closest spacing of 6x2m. Moreover, the optimum microclimate in plants at wider spacing during both the crop seasons may be helpful to retain the bearing fruits on the plants. Also the FBD and fruit set was recorded higher in plants at these spacing levels. Similar results were reported by Chundawat *et al.* (1992) and Kalra *et al.* (1994) in terms of yield per tree of guava and recorded higher yield at wider spacing. Lal *et al.* (2000) found that fruit yield per tree increased with the increase in planting distance in guava. Bal and Dhaliwal (2003) also obtained maximum fruit yield per tree at 6x5m spacing in Sardar guava.

Fruit Yield

Crop harvested during rainy season was significantly higher than winter season crop particularly from plants at wider spacing (Fig. 5). Higher fruit load might be due to heavy flowering and fruit setting during rainy season, which exhausted the tree reserves leading to poor reproductive growth during winter crop season. Similarly, the plants at wider spacing provided higher fruits compared to closely spaced plants due to more translocation of photosynthates and better microclimatic conditions in plants at such spacing. During rainy season (Fig. 5), per tree yield of 39.06 kg was recorded from plants at widest (6x5m) spacing and least yield of 16.83 kg^{-1} plant was weighed from plants at closest (6x2m) spacing. In winter season (Fig. 6), the yield per tree was recorded highest (26.33 kg $plant^{-1}$) at 6x5m spacing and minimum (3.51 kg per plant) in plants at 6x2m spacing. Similar results were reported by Chundawat *et al.* (1992) and Kalra *et al.* (1994) in terms of yield per tree of guava and recorded higher yield at wider spacing. Lal *et al.* (2000) found that fruit yield per tree increased with the increase in planting distance in guava. Bal and Dhaliwal (2003) also obtained maximum fruit yield per tree in 6x5m spacing in Sardar guava.

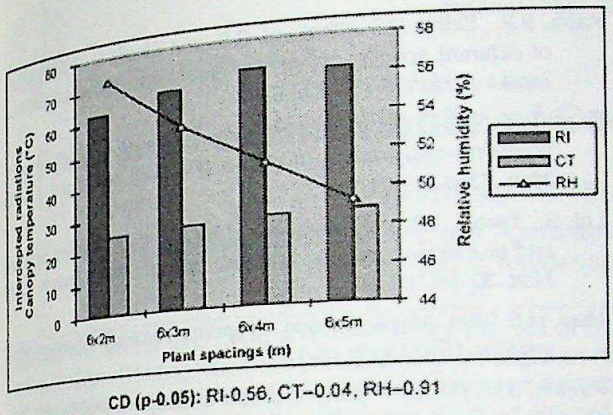
However, with increase in plant density from 278 plants per hectare to1600 plants per hectare, decrease of about 25 % yield in guava cv. L-49 was observed (Kundu, 2007). Singh *et al.* (2007) at Lucknow, recorded highest yield at 3x1.5m spacing from rainy and winter season crops, respectively and minimum at 6x6m spacing.

Fruiting density

Fruiting density of rainy season crop was noted quite higher than in winter season due to heavy flowering and fruit setting and lesser fruit drop. Perusal of Fig. 5 reveals that in rainy season crop, spacing had significant effect on fruiting density of guava plants. Maximum fruiting density (10.98) was recorded at 6x5m and 10.12 at 6x4m spaced plants. Lowest fruiting density (9.21) was obtained in plants at 6x3m spacing. Similarly, in winter season (Fig. 6),

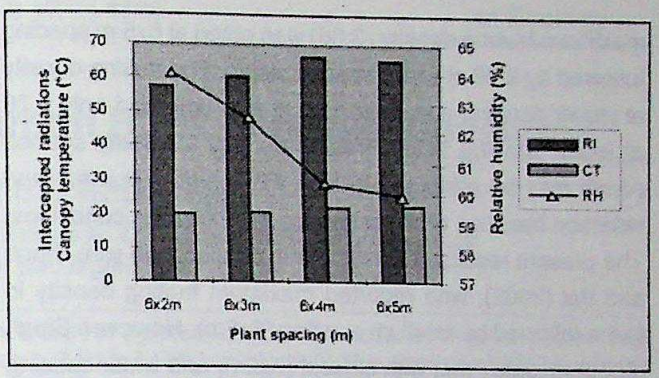
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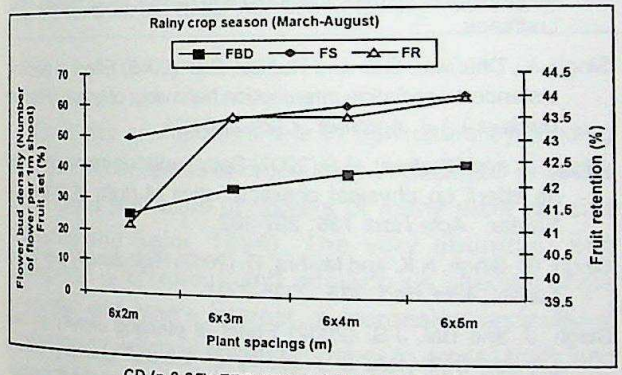
CD (p-0.05): RI-0.56, CT-0.04, RH-0.91

Fig. 1. Solar radiation interception (RI), canopy temperature (CT) and relative humidity (RH) in 'L-49' guava plants at different spacing during rainy crop season (March- August).



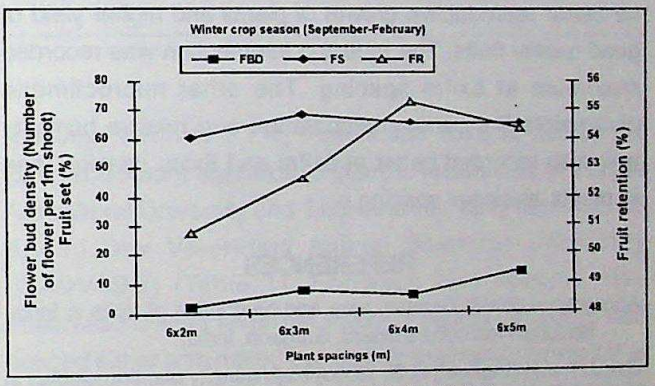
CD (p-0.05): RI-0.32, CT-0.04, RH-0.76

Fig. 2. Solar radiation interception (RI), canopy temperature (CT) and relative humidity (RH) in 'L-49' guava plants at different spacing during winter crop season (September-February).



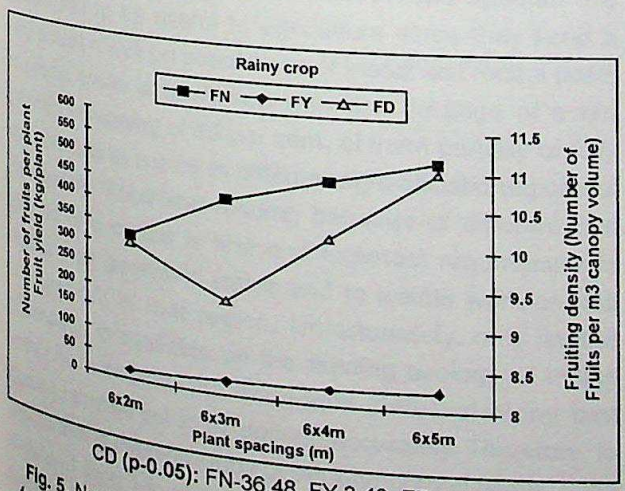
CD (p-0.05): FBD-3.11, FS-3.17, FR-NS

Fig. 3. Flower bud density (FBD), fruit set (FS) and fruit retention (FR) of rainy season crop of 'L-49' guava at different spacing.



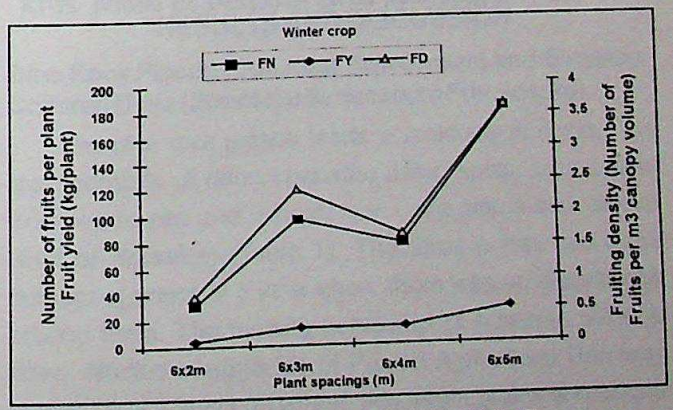
CD (p-0.05): FBD-1.28, FS-1.94, FR-1.34

Fig. 4. Flower bud density (FBD), fruit set (FS) and fruit retention (FR) of winter season crop of 'L-49' guava at different spacing.



CD (p-0.05): FN-36.48, FY-3.40, FD-1.45

Fig. 5. Number of fruits per plant (FN), fruit yield (FY) and fruiting density (FD) of rainy season crop of 'L-49' guava at different spacing.



CD (p-0.05): FN-17.69, FY-2.68, FD-0.47

Fig. 6. Number of fruits per plant (FN), fruit yield (FY) and fruiting density (FD) of winter season crop of 'L-49' guava at different spacing.

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maximum fruiting density (3.66) was noted at 6x5 m spacing followed by 2.38 at 6x3m spaced plants. The fruiting density at closer spacing was quite less; it was recorded only 0.76 at 6x2m spacing level. Fruiting density in widely spaced plants may be attributed to high FBD, higher fruit set and retention because of better canopy microclimatic conditions. The present results obtained are in consonance with Singh and Bal (2002), who reported maximum fruiting density in 6x4m followed by medium spacing (6x5m). However, Singh (2006) revealed that with closest (6x2m) and wider spacing (6x4m and 6x5m) the yield efficiency was more compared to 6x3m spacing in both rainy and winter season guava cv. L-49.

Thus, it may be concluded that the plant spacing of 6x4m and 6x5m may be exploited because, better microclimatic conditions prevail under such plant density for better reproductive growth of plants and higher yield of good quality fruits. The radiation interception was recorded maximum at 6x4m spacing. The other microclimatic parameters like canopy temperature and relative humidity was also recorded better at 6x4m and 6x5m spacing than in plants at closer spacing.

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Indian Journal of Ecology

Food and Feeding Habits of Common Birds of Agroecosystems

Navdeep Kaur and C.K. Dhanju

Department of Zoology, Punjab Agricultural University, Ludhiana-141004, Punjab, India
E-mail: navdeepkaur.pau@gmail.com

Abstract: The kind of food taken and the foraging activities of common birds of agroecosystems were observed in order to know their economic status. Feeding habits of common birds were observed randomly (8AM to 6 PM) from March 2010 to September 2011 in different agrifields, orchards, residences of PAU, Ludhiana city and dairy farm of GADVASU. Blue rock pigeon took dried chapatis, dalia, soozi, wheat flour, wheat, rice, bajra grains and siliqua; eurasian collared dove fed on wheat, rice, bajra grains and siliqua; rose ringed parakeet fed on seeds of *Brassica*, corn and bajra, mango, guava and other fruits; common myna took insects, dried chapatis, rice grains, cooked rice, cockroaches, corn and garbage waste; house crow consumed lot of things such as dried chapattis, bread, wheat grains, insects, larvae, earthworm, ticks, dead rats, dogs, owlets, pigeon etc, corn, mango fruit and garbage waste; common babbler fed on dried chapattis, mulberry fruit, insects; cattle egret takes ticks, insects, red wattled lapwing feeds on insects and pariah kite fed on rat and garbage waste. This threw light on the beneficial and harmful aspects of these birds as they consume the insect and rodent pests of agroecosystems as well as damage agricultural crops and fruits.

Key Words: Common Birds, Agroecosystems, Food, Pests.

Birds play an important role in agriculture by feeding on insects, rodent pests of crops, help in dispersal of seeds and in cross pollination in flowers of many plant species (Dhindsa and Saini, 1994). The very abundant and widespread grainivorous and omnivorous species come in conflict with man's interest of increasing agricultural production by inflicting economic injury to crops, fruits and stored grains. There are about 1200 species of birds occurring in the Indian subcontinent, at least 150 of them are reported to feed on seeds and fruits of different crops and only 25 species (about 2.1%) inflict serious damage to crops during vulnerable growth stages (Ali and Dillon, 1983).The insectivorous and carnivorous species are considered to be useful to agriculture since they keep a very potent check on populations of insect and rodent pests of crops. India is bestowed with rich heritage of avian diversity consisting of 85 per cent, of them partially or fully insectivorous in nature in different agro-climatic regions of the country. Food and feeding behavior of different bird species of a region is first and foremost requirement to assess their economic status and to initiate work on bird management in that region. Unfortunately, only limited information is available on the feeding ecology of Indian birds. As a sequel, the economic status of many bird species remains yet to be defined accurately. Therefore, to assess this, a detailed study of the kind of food taken by the birds and their foraging activities were noticed for some common birds in agroecosystems.

MATERIAL AND METHODS

Feeding habits of common birds were observed randomly (8AM to 6 PM) from March 2010 to September 2011 in different agrifields, orchards, residences of Punjab Agricultural University and Ludhiana city, dairy farm of Guru Angad Dev Veterinary Animal Sciences University (GADVASU) (Table 1). For each bird species, five observations were taken per month. Feeding behaviour was noticed either with naked eye or with the help of binocular at a distance from the bird in order to avoid the disturbance to birds. Birds were observed for the type of food material they consumed i.e. grains, seeds, insects, fruits etc. On the basis of these observations, the birds were categorized as grainivorous, frugivorous, omnivorous, insectivorous or carnivorous.

RESULTS AND DISCUSSION

Blue Rock Pigeon (*Columba livia* Gmelin) and Eurasian Collared Dove (*Streptopelia decaocto* Frivaldszky)

The blue rock pigeon feeds voraciously in flocks. The food consists of dried chapatis, dalia, soozi, wheat flour from residences and wheat, rice, bajra grains and siliqua (fruit of *Brassica*) (Table 1). The birds consumed large number of grains at a time when there was no disturbance around them. The feeding behaviour of eurasian collared dove studied in agrifields of Punjab Agricultural Univesity showed that it feeds on wheat, rice, bajra grains and siliqua from harvested agrifields either solitary or in pairs alongwith flocks of blue rock pigeon. Both these species are grainivorous .

Columba and *Streptopelia* are ground feeders and feed on grains of paddy, wheat, millet, jowar (*Sorghum* sp.) and other cereals and pulses. The blue rock pigeon very often

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feeds on seeds of mustard, linseed and various weeds as also reported by Patel (2011) The pigeons feed on millet grains during the grain maturity stage, causing a considerable loss.

Rose Ringed Parakeet (*Psittacula krameri* Scopoli)

Observations on feeding habits of rose ringed parakeet indicated that this species feeds in flocks on seeds of *Brassica*,corn and bajra from harvested agrifields and mango, guava and other fruits in orchards and residences (Table 1). This species is frugivorous in nature.

According to Kushwaha and Kumar (2007), the rose ringed parakeets are frugivorous and the gut contents recorded in these adult birds contained maize grains, groundnut, guava fruits, mango, jamun, anthers and tree barks in different crop seasons. The rose ringed parakeet often bands itself into large flocks and is highly destructive at all times to crops and orchard fruit by gnawing and wasting far more than it actually eats (Ali, 2002).

Common Myna (*Acridotheres tristis* Linnaeus)

The feeding behavior of common myna studied in agrifields, orchard of PAU and residences of PAU and Ludhiana city indicated that it takes insects from grass ground, ploughed fields, water tunnels in wheat fields, irrigated rice fields; dried chapatis, rice grains, cooked rice, cockroaches from residences; corn and garbage waste (Table 1). The common myna either feeds in flocks or at least in pairs and is a surface feeder. This bird is omnivorous in nature.

Earlier studies also revealed that common myna is omnivorous which may consume fruits (Brochier *et. al.* 2010) but the principal diet consists of insects (Ali *et al.* 2010).

House Crow (*Corvus splendens* Vieillot)

It feeds on dried chapatis and bread in residences, wheat grains in fields as well as residences, insects, larvae, earthworm from ploughed and irrigated fields ticks from buffalo ears dead rats, dogs, owlets, pigeon, corn mango fruit and garbage waste (Table 1). This species either feeds solitary or in flocks. This revealed the omnivorous nature of house crow which also depicted that it act as a scavenger of environment and can control the pests of crops as well as itself also act as serious pest of crops .

According to Khan *et al.* (2007) the crow is a primary consumer and omnivorous in nature, foraging in small flocks throughout the day on farm crops, livestock farms, and in residential areas. Ali (2002) reported that house crow has no particular food preferences and eat almost anything, dead sewer rat, offal, carrion, kitchen scraps and refuse, locusts, termites, fruit, grain and eggs or fledgling birds pilfered from nests.

Common Babbler (*Turdoides caudatus* Dumont)

It feeds on dried chapatis and mulberry fruit from residences; insects lying on dry leaf debris in orchards and on boundaries of agrifields with low vegetation and it feeds in flocks (Table 1). This species is omnivorous. Ali (2002) reported that common babbler feeds on ground and scuttle along like rats through thorn, scrub and thickets and are loth to fly.

Cattle Egret (*Bubulcus ibis* Linnaeus)

The feeding habits of cattle egret observed in agrifields of PAU and dairy farm of GADVASU showed that it takes ticks from buffalo ears; insects from irrigated wheat and rice fields as well as from ploughed fields (Table1). This species feeds individually as well as in flocks of 4-5 and usually feeds with house crow and common myna following tractors in ploughed fields and the neck movements were observed while engulfing food. The regurgitated pellets collected from breeding sites of this species showed the presence of insect body parts. Thus, the cattle egret is insectivorous in nature.

According to Maddock (1990) the cattle egrets are insectivorous with almost 98 per cent reliance on orthopterans. Mukherjee (2000) reported that cattle egrets which used to once feed in close association with grazing cattle have now shifted themselves behind tractors in inundated agricultural fields.

Red Wattled Lapwing (*Vanellus indicus* Boddaert)

The feeding behavior of red wattled lapwing (*Vanellus indicus*) indicated that this bird species feeds as solitary or in flocks aligning themselves in a straight line taking insects from ploughed and irrigated fields (Table 1). Thus, this bird species is also insectivorous in nature. Ali (2002) reported that the food of red wattled lapwing consists of insects, grubs, mollusks etc.

Pariah Kite (*Milvus migrans* Boddaert)

The pariah kite were also observed in agrifields and residences of PAU and Ludhiana city for their feeding behaviour. This species feeds as a solitary as well as in flocks. The food comprised of rat from residences and agrifields; garbage waste (which contain some fleshy material) (Table 1). Thus, this species is carnivorous. Pariah kites have been recorded in large numbers on waste accumulations generated by human activities, including rubbish dumps, markets, fishing-ports and abattoirs and thus act as a scavenger (Shiraishi *et al.*, 1990). The rats and mice, which are forced to come out of their burrows from the harvested wheat and sugarcane fields, are caught by pariah kites and the house crows (Beg *et. al.*, 2010).

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Table 1. Feeding behavior of common birds of agroecosystems

S. No.	Species	Areas observed	Type of food	Special feature of feeding Behaviour	Conclusion
1.	Blue rock pigeon (*Columba livia* Gmelin)	Agrifields of PAU; Residences of PAU and Ludhiana city	Dried chapatis, dalia, soozi, wheat flour from residences; wheat, rice, bajra grains from residences as well as harvested agrifields, siliqua (fruit of *Brassica*) from agrifields	Feed in flocks, voracious feeder	Grainivorous
2.	Eurasian collared dove (*Streptopelia decaocto* Frivaldszky)	Agrifields of PAU	Wheat, rice, bajra grains from harvested agrifields	Feeds as solitary or in pairs, feed alongwith flocks of blue rock pigeon	Grainivorous
3.	Rose ringed parakeet (*Psittacula krameri* Scopoli)	Agrifields and orchard of PAU	Siliqua , corn, bajra; from harvested agrifields mango fruit, Guava,	Feed in flocks	Frugivorous
4.	Common myna (Acridotheres tristis Linnaeus)	Agrifields, orchard of PAU; Residences of PAU and Ludhiana city	Insects from grass ground, ploughed fields, water tunnels in wheat fields, irrigated rice fields; dried chapatis, rice grains, cooked rice, cockroach from residences; corn; garbage waste	Feed in flocks or at least in pairs, Surface feeder	Omnivorous
5.	House crow (*Corvus splendens Vieillot*)	Agrifields, orchard of PAU; dairy farm of GADVASU, Residences of PAU and Ludhiana city	Dried chapatis and bread; wheat grains in fields as well as residences, insects, larvae, earthworm from ploughed and irrigated fields; ticks from buffalo ears; dead rats, dogs, owlets, pigeon etc; corn; mango fruit; garbage waste	Feeds as solitary as well as in flocks	Omnivorous
6.	Common babbler (*Turdoides caudatus* Dumont)	Agrifields, orchard of PAU; Residences of PAU and Ludhiana city	Dried chapatis and mulberry fruit from residences; insects lying on dry leaf debris in orchard and on boundaries of agrifields with low vegetation	Feed in flocks, Surface feeder	Omnivorous
7.	Cattle egret (*Bubulcus ibis* Linnaeus)	Agrifields of PAU and dairy farm of GADVASU	Ticks from buffalo ears; insects from irrigated wheat and rice fields as well as from ploughed fields	Feed individually as well as in flock of 4-5, usually feed with house crow and common myna following tractors in ploughed fields, neck movements while engulfing food	Insectivorous
8.	Red wattled lapwing (*Vanellus indicus* Boddaert)	Agrifields of PAU	Insects from ploughed and irrigated fields	Feed as solitary or in flocks aligning themselves in a sraight line	Insectivorous
9.	Pariah kite (*Milvus migrans* Boddaert)	Agrifields of PAU; Residences of PAU and Ludhiana city	Rat from residences and agrifields; garbage waste	Feeds as solitary as well as in flocks	Carnivorous

The detailed observations on the feeding habits of these common birds revealed that out of these, two species; blue rock pigeon and eurasian collared dove were grainivorous, one i.e. rose ringed parakeet was frugivorous, three; common myna, house crow and common babbler were omnivorous, two; cattle egret and red wattled lapwing were insectivorous and one; pariah kite was carnivorous and thus throw light on their beneficial and harmful aspects. They consume the insect and rodent pests of agroecosystems and the household wastes as well as damage agricultural crops and fruits. Thus this study may be of great significance to develop management strategies for maintenance of useful birds and control of pest bird species.

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Analysis of Biomass and Primary Productivity Pattern of an Agroecosystem

Mayank Singh , O.P. Singh Vatsa and M.P. Singh*

Department of Botany, T.D.College, Jaunpur-222002, U.P., India.
**E-mail: mahendrapratapsinghtdpg@gmail.com*

Abstract: Present paper deals with changes in biomass and net primary productivity of mixed winter crop (wheat and mustard) and weeds near 'Gujar Tal' (Jaunpur) at sloppy lake margins (50×200 m) distinguished into two ecological zones(upper and lower).In two zones maximum biomass of mixed crop(wheat and mustard) was at 120 days, whereas of weeds at 105 days of crop sowing. Zone - wise mixed crop had maximum biomass at the lower zone, i.e. near the lake water(wheat 1091.12g m^{-2} and mustard 739.88g m^{-2}), whereas the maximum biomass of different components of crops varied in the two distinct zones. Percentage contribution of crops and weeds in the total plant community biomass varied at different ages of crop plant. Productivity of mixed crop and dominant weed was observed to be maximum at 105 days (Wheat -*Triticum aestivum* Linn.22.91g m^{-2} day^{-1}; mustard-*Brassica campestris* Linn.19.23g m^{-2} day^{-1}; dominant weed *Cynodon dactylon* (Linn.)Pers.4.44g m^{-2} day^{-1}) , in contrast ,'other weeds' or remaining weeds (1.06g m^{-2} day^{-1}) at 90 days. In this mixed crop the maximum grain yield of wheat was 3.18 ton ha^{-1} and the average tiller density was 108.07 tillers m^{-2}, whereas, the mustard yield was 0.50 ton ha^{-1} with average plant density of 2.08 plants m^{-2} both at maturity of the mixed crop at the age of 120 days of crop plant during per cropping season(from mid of November,2008 to mid of March,2009). Analysis of variance for standing total biomass of crop community has been done, where source of variation at different ages of crop plant was significant ($p< 0.01$) in both the zones, i.e. upper and lower.

Keywords: Agroecosystem, Biomass, Lake margin, Productivity

India is an agrarian country since the beginning of civilization of the nation and its economy significantly depends on the agricultural production. The demand of ever increasing human population on food resources is tremendous. Maximization of production from agricultural lands is a must. In the quest of increasing production, lake margins are also used generally for winter cropping which experience natural calamities like flood, drought, silting and erosion. Production ecology deals with production processes and productivity by green plants, herbivores and carnivores in any ecosystem. 'Perhaps the most fundamental dimension of any ecosystem is its productivity - the rate of creation of organic material by photosynthesis primarily, per unit area and time (Whittaker, 1970)'.

The structural parameter, biomass and functional parameter, production are essential for ecosystem analysis (Reichle,1975).Wheat is the second important crop being next to rice and contributes about 25 per cent of the total food grain production, providing food for all classes of people. Mustard is another important crop as its oil is the principal cooking medium in north India. Cultivation of crops on lake margins in the rainy season generally fails due to sudden rise in water level of the lake or some time due to shortage of water due to scanty rainfall. *Eichhornia crassipes* (Mart.)Solms. a noxious weed present in the lake creating problem as entire paddy fields cultivation efforts usually fail during rainy season due to coverage of this particular weed in the crop fields by inundation of flood-water. Cultivation of crop is not possible during summer season due to extreme dry condition. In quest of increasing production intensive farming has started on lake margin, and mostly operative in winter season. Mixed cropping of wheat and mustard is common feature on these specialized habitats .Crop production is influenced by nutrients and soil moisture etc. from top upland to the lower down the lake margin.

Various workers have given accounts of weed flora production and competition in certain agroecosystem (Iwaki,1974;Soni and Ambasht, 1977; Ambasht and Chakhaiyar, 1979; Singh and Ambasht, 1986; Singh and Singh, 1997). Genetic variability of wheat lines for grain yield and components character grown under sodic and waterlogged condition has been worked out(Singh *et al.*,2006). But this kind of study near lake margin are a few in tropical climate. Therefore, present study has been conducted to quantify the biomass and primary productivity pattern of a winter agroecosystem near 'Gujar Tal' with respect to mixed crop and weeds in two different zones, i.e. upper and lower.

MATERIAL AND METHODS

Study site

This study was carried out near 'Gujar Tal'(24°6'-25°5'N and 80-82°E longitude)in the north western region of Jaunpur (U.P.) 28 km. from the city and 1.5 km to the west of Khetasarai market. The study site (50×200 m) was divided

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into two equal zones, i.e. upper (10 to 15°) and lower (5 to 10°) slope. These zones differed with respect to degree of slope, number of days of inundation and soil moisture content etc. The upper zone was partly flooded in the last week of July and first fortnight of August but lower zone was fully inundated after first fortnight of July to September during the year of the study .The cultivation of crops on these slopes are usually done during winter season only due to extremely dry condition in summer and rise of water level and some time scanty of rainfall, during rainy season. The texture of soil in two distinct zones (upper and lower) was more or less sandy clay loam in first depth (0-10 cm) and clay loam in last two depths(10-20 and 20-30 cm).The soil pH of the study site varied alkaline side between 7.0 to 8.0.

The climate is typically monsoonic with three different seasons viz. summer, rainy and winter. The total rainfall from April, 2008 to March, 2009 was 1346.8 mm out of which about 1295.4 mm was during rainy season and it was only 2.0 mm during winter crop period, including 49.4 mm the casual summer rain.

Crop operation

After the flood-water receded, ploughing was done at study site in the second week of November. In the middle of November wheat(*Triticum aestivum* , Linn.-variety *Malvi*, 234)and mustard (*Brassica compestris* Linn-variety *Varuna*, 59)were sown together by applying urea 50 kg ha^{-1} and DAP-Di Ammonium Phosphate 50 kg ha^{-1} fertilizers (equivalent to 32 kg. nitrogen and 23 kg. phosphorous) at the sowing time. Irrigation of crop with lake water was done whenever required during winter cropping.

Sampling method and calculation

On the basis of Importance Value Index (IVI)*Cynodon dactylon*(Linn.)Pers. was the most dominant weed accepted by other ecologists (Muller-Dombois and Ellenberg, 1974; Singh and Ambasht,1986;Singh and Singh,1997).Dominant weed (*C.dactylon)* was studied separately and the remaining weeds were put together as 'other weeds'. Seed production of mixed crop was determined only in the last sampling. Short term harvest method was followed to determine the biomass and dry matter production (Odum, 1960). In order to sample the shoots and roots intact of different species of the community, the core technique, as recommended by Dahlman and Kucera (1965) has been followed in the present investigation. Sampling was done fortnightly by excavating monoliths in triplicate on 25x25 cm area up to a depth of 30 cm (Goodall,1952 and Golley,1965) from two different zones. Underground part of some plants penetrate deeper than 30 cm, but more than 95 per cent of the underground biomass was found to be concentrated in the top 30 cm soil layer. Hence monoliths were dug up to 30 cm depth only. The harvested plant material was washed gently with water in wire-cage avoiding root breaking as few as possible. Samples were separated into wheat, mustard, dominant weed (*C.dactylon*) and 'other weeds', and samples of each, including root and shoot were oven dried at 80°C for 48 hrs and weighed to find out biomass.

Productivity has been calculated on dry weight basis and expressed in terms of g m^{-2} day^{-1}. The seed production of the mixed crop was determined only in the last sampling at the age of 120 days of crop plant, after separating them from husk. Farmers have kept watch to check grazing by cattle and wild animals.

Analysis of variance was applied (Campbell, 1974) to the standing total biomass of the community and standard error has been calculated for mixed crop and weeds biomass at different ages of crop plants.

RESULTS AND DISCUSSION

Weed Occurrence

There were altogether 39 weed species recorded between November,2008 to March, 2009 during winter crop period at study site. Weed density (240.00 individuals m^{-2}) was found to be maximum at later stage crop flowering in February, 2009.*C.dactylon* was most dominant weed throughout the cropping season in both the zones on the basis of IVI values. Its overall density exceeded that of the crop in both the zones at the stage of maturity of crop during late February.

During winter cropping some weed species were present throughout the cropping season; others showed shorter life span while still others were extremely ephemeral. Their appearance is controlled by dormancy, germination requirements (Branchley and Warington, 1933) and soil moisture (Roberts and Marget,1980). Invasion by aggressive alien weed like *Parthenium hysterophorous* Linn ('Gajar ghas') might have eliminated the native species. *C.dactylon* was most dominant weed on the basis of IVI values, i.e.49.16 (Dec., 2008) and 70.90(Feb.,2009) mostly due to its fast tillering capacity as a mode of vegetative propogation.

Plant biomass and net productivity

Maximum biomass of mixed crop (wheat and mustard) was at 120 days (first fort night of March), whereas of weeds at 105 days (last fort night of February). The peak value of biomass was more for wheat (1091.12 g m^{-2}) then for

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mustard (739.88 g m^{-2}) at the age of 120 days both in the lower zone. In contrast among weeds, maximum biomass values of dominant weed *C.dactylon* was 195.75 g m^{-2} followed by 'other weeds' 64.42 g m^{-2} both in the lower zone at the age of 105 days (Fig.1).

The higher values of biomass of both crops and weeds (2044.52 g m^{-2}) were in the lower zone at the age of 120 days crop. It might be due to better soil moisture (Singh *et al.*,2010),span of inundation and slightly better soil nutrients(Singh *et al.*,2011) in the lower zone. This kind of trend of biomass has also been reported in riparian agroecosystem during winter cropping (Singh and Ambasht,1986;Singh and Singh,1997).Among weeds the contribution of *C.dactylon* was always high in comparison to 'other weeds' except in the beginning of the crop in the upper zone. It might be due to its competitive ability and fast tillering capacity through vegetative propagation (Fig.1). Similar trend has been reported in riparian agroecosystem (Singh and Ambasht, 1986).

Analysis of variance for standing total plant biomass has been calculated for winter crop community, where source of variation for monoliths was not significant but at different ages of crop plant variance ratio was significant ($p<0.01$) in both the zones, i.e. upper and lower (Table 1).

Percentage contribution of the total community biomass between crops and weeds at different ages with slight variation showed more or less decreasing contribution of weeds with increase of crop age. It might be due to the removal of weeds by the farmers and gregarious nature of the crop. Maximum percentage contribution of wheat (54.74%), mustard (35.98%) both were at the age of 120 days of mixed winter crop and dominant weed *C. dactylon* (13.72%) at 45 days and 'other weeds' (13.87%) at 15 days of crop in the upper zone of study site. In contrast, their respective values in the lower zone were wheat (53.37%), mustard (36.19%) both at the age of 120 days of crop, and *C. dactylon* (44.44%) at 45 days and 'other weeds' (11.11%) at the age of 30 days crop plant (Fig.2).

Productivity of mixed crop was observed to be maximum at 105 days for wheat 22.91 g m^{-2} day^{-1} (lower zone) but mustard had shown slight fluctuation among two zones, i.e 19.23 g m^{-2} day^{-1} (upper zone) at 105 days and 15.43 g m^{-2} day^{-1} (lower zone)at 90 days. In contrast, maximum productivity of dominant weed *C. dactylon* at 105 days 4.01g m^{-2} day^{-1}(upper zone) and 4.44 g m^{-2} day^{-1} (lower zone) and 'other weeds' productivity values were at 90 days 0.85 g m^{-2} day^{-1}(upper zone) and 1.06g $m^{-2}day^{-1}$(lower zone) Fig.3. Productivity of mixed crop was always high in the upper zone and weeds in the lower zone. It seems to be dominant weed (*C.dactylon*) and 'other weeds' were more sensitive to better soil moisture and nutrients, etc. which mostly prevailed in the lower zone of lake margin.

On perusal of net primary productivity trend of wheat and mustard mixed crop in the present study and comparison with other works, productivity of pure mustard crop as 19.77 g $m^{-2}day^{-1}$ (Ambasht and Chakhaiyar,1979)and wheat crop 21.48g m^{-2} day^{-1} (Soni and Ambasht,1977) at fruiting stage in the agroecosystem around Varanasi .The rate of productivity was less for wheat and more for mustard in comparison to riparian agroecosystem (Wheat 23.51 g

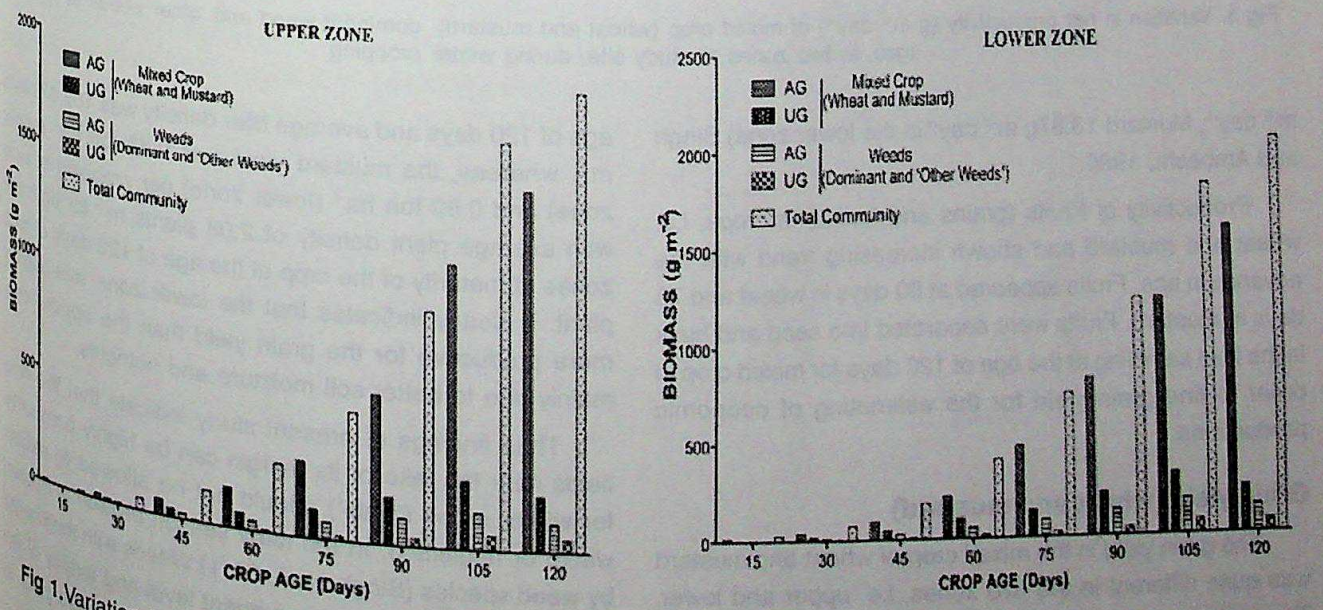


Fig 1.Variation in standing crop biomass of different components of mixed crop (wheat and mustard), associated weeds and total community at different ages in two zones

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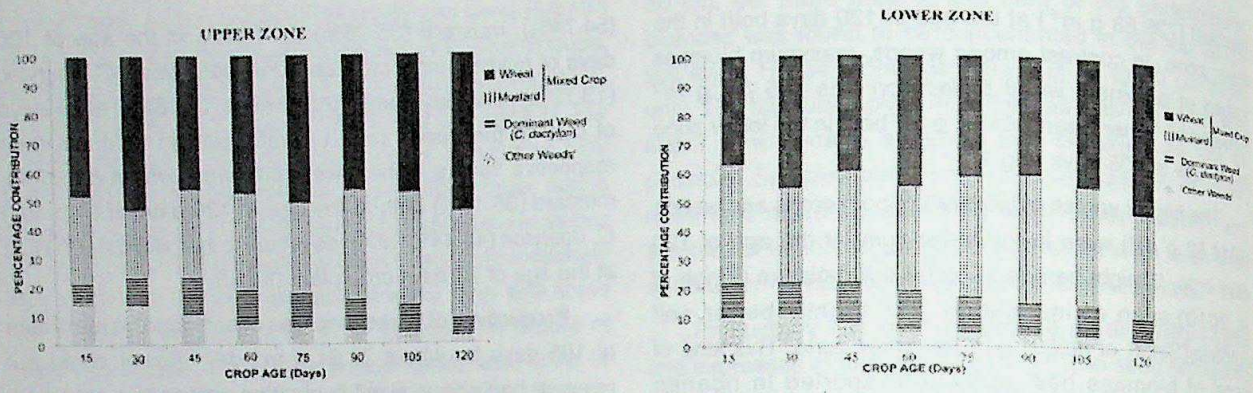


Fig 2. Variation in percentage contribution of total biomass (community) of mixed crop and weeds at different ages, in the two different zones at study site, during winter cropping

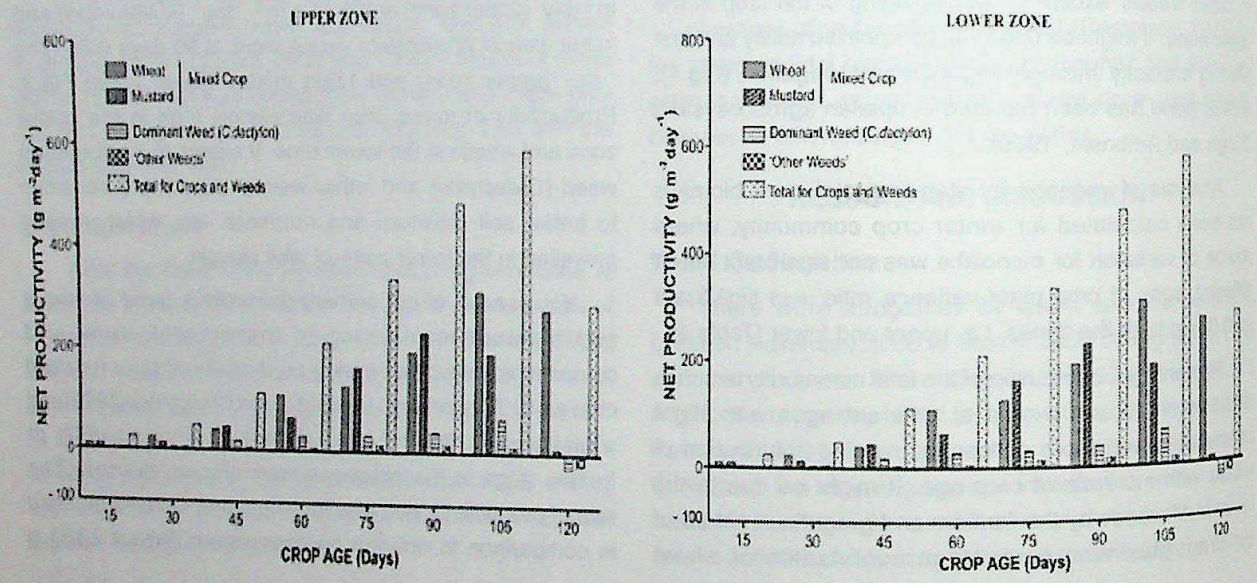


Fig 3. Variation in net productivity (g m^{-2} day^{-1}) of mixed crop (wheat and mustard), dominant weed and 'other weeds' at different ages, in two zones at study site, during winter cropping

m^{-2} day^{-1}, Mustard 13.87g m^{-2} day^{-1} in the lower zone) Singh and Ambasht, 1986.

Productivity of Fruits (grains and husks) in crops, i.e. wheat and mustard had shown increasing trend with the advance in age. Fruits appeared at 60 days in wheat and 75 days in mustard. Fruits were separated into seed and husk in the final sampling at the age of 120 days for mixed crop in order to find grain yield for the estimating of economic productions.

Grain yield (wheat and mustard)

The grain yield in the mixed crop of wheat and mustard was quite different in the two zones, i.e. upper and lower. The peak yield of wheat grain was 3.10 ton ha^{-1} (upper zone) and 3.18 ton ha^{-1} (lower zone) per cropping season at the age of 120 days and average tiller density was 108.07 tillers m^{-2}, whereas, the mustard yield was 0.48 ton ha^{-1} (upper zone) and 0.50 ton ha^{-1} (lower zone) per cropping season with average plant density of 2.08 plants m^{-2} for both the zones at maturity of the crop at the age of 120 days of crop plant. It clearly indicates that the lower zone was slightly more productive for the grain yield than the upper zone, mainly due to better soil moisture and nutrients.

Thus findings of present study indicate that the crop fields near the lake or its margin can be highly productive for winter crops ('Rabi') should not be allowed to remain waste or neglected. In the rainy season erosion is choked by weed species (Singh *et al.*, 2011).Weeds with their faster turnover rate , increase the nutrient level and fertility of the soil. Seasonal submergence and exposure also help in

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recharging fertility status of the soil. It can be an important source of production of crops to supplement the needs of increasing population.

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Effect of Plant Growth Regulators on Consumption Indices of Silkworm, *Bombyx mori* L.

B.V. Raghunath and K.C. Narayanaswamy*

Department of Sericulture, College of Agriculture, University of Agricultural Sciences GKVK, Bangalore- 560 065, India

**E-mail: kcn_uas@yahoo.co.in*

Abstract: The effect of plant growth regulators on consumption indices of silkworm larvae, *Bombyx mori* L. was observed during 2009-10. Silkworm larvae (CSR_2) topically treated with gibberellic acid at 100 µg/ml on second day of fifth instar exhibited significantly highest food consumption (455.27 g/50 larvae), digestion (234.01 g/50 larvae), growth rate (0.189), efficiency of conversion of ingested food (33.29 %), efficiency of conversion of digested food (64.71 %), approximate digestibility (51.40 %) and reference ratio (2.06) with minimum consumption index (0.568) compared to untreated silkworm larvae.

Key Words: *Bombyx mori*, Consumption Indices, Gibberellic Acid, Indole Acetic Acid, Mulberry.

The mulberry silkworm, *Bombyx mori* L. is one of the important insects exploited for commercial silk importance. India ranks second in respect of mulberry silk production, next only to China producing 19,690 MT of raw silk (Anonymous, 2010). Nutritional studies on silkworm larvae are of much importance from the point of quality silk production. Mulberry leaf consumption, digestion and utilization have an impact on the silkworm larval growth and development, which inturn is reflected on the quality of cocoon and silk. Efficiency of silkworm rearing can be enhanced by improving the nutritional status of the food that alters the physiology of the larvae to produce more silk (Ravikumar, 2003; Slansky and Scriber, 1985). The suitability of the host is determined through estimation of rate of ingestion, digestibility, conversion efficiency of food and growth rate of the animal (Englemann, 1966). Therefore, the present study was undertaken with an objective to know the effect of plant growth regulators (PGRs) on consumption indices of silkworm larvae.

MATERIAL AND METHODS

The plant growth regulators i.e., Indole Acetic Acid (IAA) (0.0001, 0.0002 and 0.0004 mg) and Gibberlic Acid (GA3) (0.05, 0.1 and 0.15 mg) were dissolved in 5 ml of absolute alcohol and the volume was made up to 100 ml with sterile distilled water to get concentrations of 0.1, 0.2 and 0.4 µg/ml, and 50, 100 and 150 µg/ml, respectively. The plant growth regulators were administered to early stage (1st day of second instar), later stage (2nd) and early + later stages of larvae by two methods *viz.*, topical application on the larvae by spraying uniformly with the help of atomizer and oral administration through feeding of plant growth regulator treated mulberry leaf. Untreated control was also maintained. The experiment was conducted at Department of Sericulture, UAS, Bangalore during 2009-10 under temperature of 25±1°C and relative humidity of 75±5%. Each treatment was replicated thrice with 50 larvae per replication. The silkworm larvae rearing (breed- CSR_2) was carried out as per the recommendation of Dandin *et al.* (2003). The food consumption and growth parameters were recorded and indices were computed by gravimetric method (Waldbauer, 1968).

RESULTS AND DISCUSSION

Food consumption

The food consumption was significantly more when silkworm larvae were treated topically with gibberellic acid at 100 µg/ml (455.27 g/50 larvae) and indole acetic acid at 0.2 µg/ml (454.85 g/50 larvae), when silkworm larvae were treated during early + later stages compared to control batch (Table 1). There is no report on effect of PGRs on food consumption to substantiate the present investigation. However, Gayathri (2005) reported that, fifth instar larvae fed with mulberry leaves treated with *Eclipta prostrata* leaf extract recorded significantly maximum food consumption compared to control. According to Murari *et al.* (2008) silkworm larvae fed with mulberry leaves treated with 6 per cent concentration of *Cucumis sativus* registered significantly higher food consumption. The extrafoliation of *Parthenium hysterophorus* (20 %) and *Tridax procumbens* (30 %) induced phagostimulant properties which stimulated larvae to consume more food (Mahesha *et. al.*, 1999). Reshma (1997) reported that silkworm larvae fed with mulberry leaves treated with potato leaf extract at growth stage registered significantly higher consumption in fourth and fifth instars as compared to control.

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Digestion

Significantly higher (234.01 g/50 larvae) digestion was observed in silkworm larvae, which were topically applied with gibberellic acid and indole acetic acid at 0.2 µg/ml (233.92 g/50 larvae) when silkworm larva were treated during early + later stages, as compared to control. The digestion was minimum in silkworm larvae which were orally administered with indole acetic acid at 0.1 µg/ml during early larval stage (Table 1). These observations are in close conformity with the findings of Thimmaraju (2008), who recorded the higher digestion with *C. annum* green fruit extract. Murari *et al.* (2008) reported that the silkworm larvae (PM x CSR_2) reared on mulberry leaves sprayed with aqueous extracts of *C. sativus* at 6 per cent concentration recorded significantly maximum food digestion during fifth instar. Gayathri (2005) reported that larvae fed with *E. prostrata* plant extract recorded significantly higher digestion as compared to normal control. Reshma (1997) also reported higher digestion in silkworm larvae when they were fed with mulberry leaves sprayed with potato leaf extract during third, fourth and fifth instars.

Consumption index (CI)

The consumption index was significantly minimum in silkworm larvae which were treated topically with gibberellic acid at 100 µg/ml (0.568) and indole acetic acid at 0.2 µg/ml (0.568), when silkworm larvae were treated during early + later stages as compared to control batch (0.585). However, the consumption index was maximum when silkworm larvae were administered orally with indole acetic acid at 0.1 µg/ml during early larval stage (Table 1). Reshma (1997) noticed that the application of potato leaf extract recorded maximum CI during third, fourth and fifth instars. Manimuthu and Isaiarasu (2010) observed that larval consumption index of the fifth instar larvae of *B. mori* increased with supplementation of *Aloe vera* tonic.

Growth rate (GR)

The maximum growth rate was registered in silkworm larvae which received topical application of gibberellic acid at 100 µg/ml and indole acetic acid at 0.2 µg/ml when silkworm larvae were treated during early + later stages compared to control batch (0.173). The growth rate was minimum among the silkworm larvae which were orally administered with indole acetic acid at 0.1 µg/ml during early larval stage (Table 1). Similar trend of GR was reported by Reshma (1997). Further, Murugan *et al.* (1998) reported that the larvae after treatment with *Tribulus terrestris* and *Boerhavia diffusa* registered (0.28 and 0.35) an increased GR during fifth instar. Further, Gayathri (2005) reported that the *E. prostrata* treatment to the larvae recorded increased GR as the age of the silkworm larvae advanced.

Efficiency of conversion of ingested food (ECI %)

The ECI was significantly maximum among the silkworm larvae which were treated topically with gibberellic acid at 100 µg/ml and indole acetic acid at 0.2 µg/ml during early + later stages as compared to control batch (Table 2). These results are similar to the findings of Thimmaraju (2008), who reported that the ECI was influenced profoundly by *C. annum* green fruit extract. Reshma (1997) reported that the potato leaf extract at growth stage increased. The present findings are also similar to the work of Murugan *et. al.* (1998), Gayathri (2005) and Murari *et. al.* (2008).

Efficiency of conversion of digested food (ECD %)

ECD explains the ability of insect to utilize the portion of food that is digested for growth and development, which varies according to the efficiency of nutrient intake by the larvae to gain in body weight. The PGRs had significant influence on ECD. However, the maximum ECD (64.71 %) was obtained when silkworm larvae were topically applied with gibberellic acid at 100 µg/ml and indole acetic acid at 0.2 µg/ml (64.65 %) during early + later stages as compared to control batch (59.33 %). While, the ECD was minimum when early stage silkworm larvae were orally administered with indole acetic acid at 0.1 µg/ml (58.96 %) (Table 2). The variation in ECD may be due to varied level of nutrient intake, quality of food, changes in the midgut activity of the silkworm larvae and also may be due to total biochemical component of leaf which has direct relationship with ECD (Basaiah, 1988). The present findings are in close agreement with the findings of Murugan *et. al.* (1998) and Thimmaraju (2008).

Approximate digestibility (AD%)

The higher AD was observed in silkworm larvae which received topical application of gibberellic acid at 100 µg/ml (51.40 %) and indole acetic acid at 0.2 µg/ml (51.43 %) during early + later stages as compared to control batch (49.85 %). The AD was minimum (49.80 %) when silkworm larvae were administered orally with indole acetic acid at 0.1 µg/ml during early larval stage (Table 2). The present results are in conformity with the findings of Reshma (1997), Murugan *et al.* (1998) and Gayathri (2005).

Reference ratio (RR)

Silkworm larvae registered significantly maximum reference ratio when treated topically with gibberellic acid at 100 µg/ml (2.06) and indole acetic acid at 0.2 µg/ml (2.06) during early + later stages as compared to control batch (1.99). But the reference ratio was minimum (1.99) in silkworm larvae which were administered orally with indole acetic acid at 0.1 µg/ml during early larval stage (Table 2). These results are in agreement with those of Thimmaraju (2008). Ravikumar (2003), also reported an increase in RR

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Table 1. Effect of PGRs on consumption, digestion, consumption index and growth rate of *Bombyx mori* L. (CSR_2) during fifth instar

PGR/ Control	Conc.	Stage of application	Consumption (g/50 larvae)		Digestion (g/50 larvae)		Consumption index		Growth rate	
			Oral	Topical	Oral	Topical	Oral	Topical	Oral	Topical
IAA	0.1 µg/ml	Early	434.36	442.23	216.32	223.19	0.586	0.581	0.172	0.176
		Early + Later	440.21	445.98	221.18	226.11	0.584	0.579	0.177	0.181
		Later	441.98	449.85	222.35	229.26	0.581	0.576	0.178	0.185
	0.2 µg/ml	Early	438.51	446.28	219.78	226.20	0.585	0.579	0.175	0.181
		Early + Later	444.28	450.74	224.78	230.06	0.579	0.576	0.181	0.184
		Later	446.62	454.85	226.70	233.92	0.577	0.568	0.182	0.189
	0.4 µg/ml	Early	436.72	444.86	218.23	225.23	0.585	0.580	0.174	0.179
		Early + Later	442.07	448.53	222.35	228.07	0.581	0.577	0.179	0.183
		Later	443.93	452.93	224.08	232.15	0.579	0.573	0.180	0.188
GA_3	50 µg/ml	Early	439.26	445.89	220.50	225.97	0.585	0.580	0.176	0.179
		Early + Later	444.01	447.82	224.55	227.48	0.579	0.577	0.180	0.182
		Later	445.63	453.04	225.77	232.22	0.577	0.573	0.181	0.186
	100 µg/ml	Early	443.24	448.02	224.05	227.63	0.583	0.577	0.179	0.182
		Early + Later	448.37	451.85	227.59	231.10	0.576	0.576	0.183	0.185
		Later	450.24	455.27	229.73	234.01	0.575	0.568	0.184	0.189
	150 µg/ml	Early	441.53	447.21	222.56	227.16	0.584	0.579	0.178	0.181
		Early + Later	445.89	449.73	225.98	229.21	0.578	0.577	0.181	0.183
		Later	447.92	454.16	227.49	233.13	0.576	0.569	0.182	0.188
Control	435.03	435.03	216.88	216.88	0.585	0.585	0.173	0.173		
CD (p=0.05)	1.655	1.655	1.655	1.655	0.006	0.006	0.006	0.006		

Table 2. Effect of PGRs on efficacy of conversion of ingested food (ECI), efficacy of conversion of digested food (ECD), approximate digestibility (AD) and reference ratio (RR) of *Bombyx mori* L. (CSR_2) during fifth instar

PGR/ Control	Conc.	Stage of application	ECI (%)		ECD (%)		AD (%)		RR	
			Oral	Topical	Oral	Topical	Oral	Topical	Oral	Topical
IAA	0.1 µg/ml	Early	29.37	30.30	58.96	60.04	49.80	50.47	1.99	2.02
		Early + Later	30.33	31.27	60.37	61.67	50.24	50.70	2.01	2.03
		Later	30.66	32.12	60.95	63.02	50.30	50.96	2.01	2.04
	0.2 µg/ml	Early	29.90	31.24	59.66	61.63	50.12	50.69	2.01	2.03
		Early + Later	31.24	31.93	61.75	62.55	50.59	51.04	2.02	2.04
		Later	31.51	33.25	62.08	64.65	50.76	51.43	2.03	2.06
	0.4 µg/ml	Early	29.72	30.87	59.48	60.97	49.97	50.63	1.99	2.03
		Early + Later	30.83	31.73	61.30	62.39	50.30	50.85	2.01	2.04
		Later	31.10	32.82	61.61	64.04	50.47	51.26	2.02	2.05
GA_3	50 µg/ml	Early	30.08	30.89	59.91	60.96	50.20	50.68	2.00	2.03
		Early + Later	31.07	31.54	61.44	62.09	50.57	50.80	2.02	2.03
		Later	31.37	32.47	61.92	63.34	50.66	51.26	2.03	2.05
	100 µg/ml	Early	30.72	31.52	60.78	62.04	50.55	50.81	2.02	2.03
		Early + Later	31.76	32.10	62.56	62.77	50.76	51.15	2.03	2.05
		Later	31.98	33.29	62.67	64.71	51.02	51.40	2.04	2.06
	150 µg/ml	Early	30.48	31.26	60.47	61.55	50.41	50.79	2.02	2.03
		Early + Later	31.33	31.71	61.82	62.21	50.68	50.97	2.03	2.04
		Later	31.61	33.13	62.24	64.53	50.79	51.33	2.03	2.06
Control	29.58	29.58	59.33	59.33	49.85	49.85	1.99	1.99		
CD (p=0.05)	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015		

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in the larvae of PM x CSR_2 compared to PM x NB_4D_2. Anatharaman *et. al.* (1993) observed that the reference ratio values depend on age, quality of food, retention time, rate of enzyme activity and ingestion rate.

The topical application of gibberellic acid at 100 µg/ml followed by indole acetic acid at 0.2 µg/ml were the best when consumption indices were considered. It is concluded that the application of plant growth regulators (IAA and GA_3) with appropriate concentration are beneficial in the sericulture industry since PGRs directly influence the consumption pattern of silkworm which in turn results in higher productivity and higher returns.

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Pesticide Residues in Food Items: A Study of Organized and Unorganized Retail Outlets in Ludhiana District

Sonika Sharma, Jasvinder K. Sangha and Balwinder Singh[1]

Department of Food and Nutrition, CoHSc, Punjab Agricultural University, Ludhiana-141004, Punjab, India
[1]Department of Entomology, Punjab Agricultural University, Ludhiana-141004, Punjab, India
E-mail: drsonika@pau.edu

Abstract: Samples of cereals and raw vegetables were collected from 30 households along with the information about sourcing of the food item i.e. from organized retail outlets or unorganized retail outlets. No pesticide residues were found in the rice and wheat flour samples sourced from both organized and unorganized retail outlets. Except for cauliflower, pesticide residues found in the samples of various raw vegetables were lower than (Maximum Residue Limits) MRL listed in the official standards of Codex. The pesticide residue of chlorpyriphos (0.200 ppm) in cauliflower sample was above the MRL recommended by Codex. The samples of cauliflower sourced from the organized retail outlet were having higher residues compared to the samples gathered from the unorganized retail outlets. No pesticide residue was found in brinjal and cabbage samples of organized sector whereas brinjal samples from unorganized sector had pesticide residues of triazophos: 0.117ppm and chlorpyriphos: 0.04 ppm and that of cabbage had chlorpyriphos: 0.1 ppm and endosulfan total: 0.01 ppm. Pesticide residues were there in case of tomato [Organized: chlorpyriphos: 0.056 ppm, profenophos: 0.310 ppm and Unorganized: chlorpyriphos: 0.025 ppm] and okra [Organized: chlorpyriphos: 0.012 ppm, triazophos: 0.013 ppm, ethion: 0.017 ppm and Unorganized: chlorpyriphos: 0.05 ppm, endosulfan Total: 0.02 ppm, malathion: 0.534 ppm] thus, indicating the presence of pesticide residues in tomato and okra samples obtained from both organized and unorganized sectors. It was also found that the majority of the pesticides found in the vegetable samples were not in the official recommended list of Codex Alimentarius Commission.

Key Words: Brinjal, Cabbage, Cauliflower, Maximum Residue Limit, Pesticide Residues, Okra, Tomato.

People today have become more health conscious, as an increase in the intake of fresh fruit and vegetables has been observed in recent years. Consumers are prone to recognize the nutritional benefits of consuming higher amount of fresh vegetables and fruits. But still, the question of safety of these foods arises due to the presence of residues of plant treatment products. Exposure to pesticides, both occasionally and environmentally, causes a range of human health problems. Their excessive use/misuse, their volatility and long distance transport eventually results in widespread environmental contamination. While remarkable progress has been made in the development of effective pesticides, the fact remains that a very small fraction of all applied pesticides is directly involved in the pesticidal mechanism. This implies that most of the applied pesticides find their way as 'residue' in the environment into the terrestrial and aquatic food chains where they undergo concentration and exert potential, long term, adverse health effects. According to the available data in 2007-08, monthly per capita consumption in urban India stood at Rs. 64 and the figure for rural India was Rs. 49 per capita. Share of vegetables in the monthly consumption expenditure was estimated at 6.3 per cent and 4.4 per cent for rural and urban areas, respectively.

Pesticides are used by the vegetable growers for commercial benefits. At times, non-recommended pesticides are used and the doses/sprays of the recommended pesticides are higher as compared to the recommendations. Excessive pesticide residues can be harmful to the human health and can lead to a number of chronic ailments. Effective sourcing is considered as a tool to mitigate the incidence of such chronic ailments. The present study was conducted to estimate the pesticide residues in samples of selected vegetables and cereals and to compare the samples sourced from organized and unorganized retail outlets.

MATERIAL AND METHODS

For the purpose of carrying out pesticide residue analysis, samples of selected food items were collected from 30 household in Ludhiana district during 2010. Fifteen households each were included from the rural and the urban areas. Samples of various vegetables namely cauliflower, brinjal, cabbage, tomato and okra were procured. The vegetables were chopped and a representative sample of 50 g was taken. The sample was blended with 200 ml of acetone and kept overnight for extraction. The extract was filtered in 11 separatory funnels using glass wool. Again, the residual pulp was blended twice with acetone and filtered again into the same 11 separatory funnels. The filter was diluted with 600 ml of 5% NaCl solution. The aqueous phase was partitioned twice with 75 ml dichloromethane and 75 ml of n-hexane. The dichloromethane/hexane layers containing the pesticide residues were drained into 500 ml

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beakers through 1.5 inch layer of anhydrous sodium sulphate supported on a pre washed glass wool in a funnel. The aqueous was re-extracted with additional 75 ml each of dichloromethane and hexane and the solvent layers were passed through the same anhydrous sodium sulphate and combined with the extract already obtained. The combined extract was concentrated to 5 ml under rotary vacuum evaporator. The extracts, thus obtained, were cleaned up by column chromatography using silica gel (60-120 mesh) as an absorbent. Before using, the silica gel was washed with dichloromethane and acetone followed by the activation at 110°C for 2h. The extract was mixed thoroughly with a mixture of silica gel (20g), anhydrous sodium sulphate (10g) and activated charcoal (2g). A glass column (60 cm × 2.0 cm i.d.) containing 40 ml dichloromethane supported on a cotton plug was prepared. Sample slurry was prepared using dichloromethane and transferred to the column. The column was allowed to stand for 90 minutes and the dichloromethane present in the column was eluted drop wise. When about 5 ml dichloromethane remained above the surface of the absorbent, the extract was eluted with 150ml of freshly prepared solvent mixture of dichloromethane: acetone (1:1, v/v). The eluates, thus obtained, were concentrated to 2-3 ml. About 150 ml hexane was added and again concentrated to 2-3 ml. The contents were transferred to a graduated test tube and the final volume was made using n-hexane (Chahal *et al.*, 1999)

Estimation of residues: Estimation of residues was carried out by Gas-Liquid Chromatography (GLC) equipped with 63Nielectron capture detector (ECD)and Nitrogen-phosphorous detector(NPD) as given by Gupta *et al.* (1998).

RESULTS AND DISCUSSION

Out of the 30 households from whom food samples were collected, eight households reported sourcing of vegetables from the organized retail outlet while the remaining twenty two households were sourcing the vegetables from the elaborate.

Cereals

Analysis of the food samples revealed that there were no pesticide residues in rice and wheat flour samples collected from 30 households. Absence of pesticide residues in the rice and wheat flour samples can be due to low use of pesticides and long interval between application and harvest. Further, the processing of rice (milling, polishing etc.) and wheat (washing and grinding) could have led to mitigation of pesticide residues (in case any residues were there at the post harvest stage). Holland *et al.* (1994) also reported that residues of pesticides in food are influenced by the storage, handling and processing that occurs between harvesting of raw agricultural commodities and consumption of prepared foodstuffs. Kaushik *et al.* (2008) also conducted a review on food processing a tool to pesticide residue dissipation and came out with the conclusion that food processing treatments such as washing, cooking, milling and parboiling lead to a significant reduction of pesticide residues.

Cauliflower

Chlorpyriphos was found in the samples sourced from both organized as well as unorganized retail outlets. The extent of presence of chlorpyriphos (0.2 ppm) was more in the samples sourced from organized retail outlets as compared to the ones sourced from unorganized sector (0.15 ppm) (Table 1). But there was no significant difference in the mean values. Chlorpyriphos residue in both the cases was found to be more than the maximum residue limit of 0.05 ppm prescribed by Codex Standards. Further, it can be seen that the samples sourced from unorganized sectors contained residues of quinaphos, profenophos and ethion. These pesticides do not figure on the official standards of Codex for cauliflower. Thus cauliflower sourced from unorganized retail outlet had more pesticide residues as compared to the ones sourced from organized outlets.

Brinjal

The samples sourced from organized retail outlets were not having any pesticide residue at all, whereas the samples sourced from unorganized sector had residues of chlorpyriphos and triazophos. Both of these pesticides do not figure in the official standards prescribed by Codex Alimentarius Commission for brinjal. Thus, brinjal sourced from unorganized retail outlet had higher pesticide residues as compared to the ones sourced from organized outlets.

Bharath *et. al.* (2009) also investigated the pesticide residues in vegetables including brinjal, cucumber, okra, ridge gourd, tomato and water samples collected from Rangareddy district, Andhra Pradesh, India and revealed the presence of monocrotophos (range 0.001-0.044 mg kg"), chlorpyrifos (0.001 to 5.154 mg kg"), cypermethrin (0.001 to 0.352 mg kg") and endosulfan (0.001 to 0.784 mg kg'1). The residues of monocrotophos and endosulfan were below maximum residue limit (MRL) in all the 59 vegetable samples, while the residues of chlorpyriphos were above MRL in four samples and cypermethrin in two samples.

Cabbage

The results of the present study indicates that cabbage samples sourced from the organized retail outlets (Table 1) had no pesticide residues. Whereas the cabbage samples sourced from the unorganized retail outlets contained pesticide residues of chlorpyriphos and endosulfan. The level of chlorpyriphos residue found in the

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Table 1. Pesticides Residues in vegetables (ppm): Organized vs. Unorganized Sector Samples

Pesticide	Organized Sector (n=8)	Unorganized Sector (n=22)	t-value	Codex Official Standard (ppm)
Cauliflower				
Chlorpyriphos	0.200 ± 0.077	0.155 ± 0.061	1.66	0.05
Quinaphos	-	0.105 ± 0.014	-	#
Profenophos	-	0.042 ± 0.008	-	#
Ethion	-	1.340 ± 0.801	-	#
Brinjal				
Chlorpyriphos	-	0.040 ± 0.008		#
Triazophos	-	0.117 ± 0.017		#
Cabbage				
Chlorpyriphos	-	0.10 ± 0.017		1.00
Endosulfan	-	0.01 ± 0.009		#
Tomato				
Chlorpyriphos	0.056 ± 0.067	0.025 ± 0.030	1.69	0.5
Profenophos	0.310 ± 0.022	-	-	#
Okra				
Chlorpyriphos	0.012 ± 0.002	0.05 ± 0.069	1.638	#
Triazophos	0.013 ± 0.006	-		#
Malathion	-	0.534 ± 0.022		#
Ethion	0.017 ± 0.008	-		#
Endosulfan		0.02 ± 0.019		#

MRL value not prescribed in the Codex Official Standards

samples was within the limits prescribed by Codex official standards whereas endosulfan residues were not figuring in pesticides whose MRLs have been specified by the Codex Official Standards prescribed for cabbage. Thus, cabbage sourced from unorganized retail outlet had more pesticide residues as compared to the ones sourced from organized outlets. Shah *et al.* (2000) conducted a similar study in which the samples of vegetables including brinjal, cauliflower, cabbage, Indian bean, okra, tomato, chilly and other minor vegetables from farm fields in Gujarat were analyzed for a range of organochlorine, organophosphorus and pyretheriod pesticides. Out of the 214 samples analysed, 145 were found to be contaminated with different pesticides. Monocrotophos was the major pesticide detected in the samples and exceeded permissible levels in several vegetables. Chandrasekaran *et al.* (2001) reported that out of the 164 vegetable samples taken from Tamil Nadu, 113 were found to be contaminated at the prescribed permissible limits and only 5 per cent exceeded the maximum residue limit. A study in Kanpur by Rashmi and Sasi (2001) on winter vegetables also confirmed the above findings .

Tomato

Chlorpyriphos residues were found in the tomato samples sourced both from the organized as well as unorganized retail outlets (Table 1). Level of chlorpyriphos residues were higher in case of samples sourced from organized retail outlets as compared to the ones sourced from the unorganized retail outlets. But these residues were found to be less than the prescribed limit of 0.5 ppm by official codex standards for tomato. There was no significant difference in the mean values for the residue of chlorpyriphos for tomatoes sourced from organized and unorganized retail outlets. Samples sourced from the organized retail outlets were having Profenophos to the extent of 0.310 ppm and the given pesticide does not figure in the official Codex standards prescribed for tomato.

Okra

Maximum number of pesticides were found in case of okra as compared to other vegetables. Moreover, all the pesticides found in the samples of okra were not included in the Codex Official standards prescribed for okra. Chlorpyriphos was found in the samples sourced both from the organized and unorganized retail outlets, with the samples sourced from the unorganized sector containing higher levels of chlorpyriphos as compared to the ones sourced from organized sector. Triazophos and ethion were found in the samples sourced from the organized retail outlets and malathion and endosulfan were found in the samples sourced from the unorganized retail outlets.

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There was no significant difference found in the mean value of pesticide residue of Chlorpyriphos. A similar study was reported by Singh *et. al.* (2007) who conducted a field experiment in Bihar, India, to study the residues of lambda-cyhalothrin on okra fruits following applications of 15 and 30 g ai/ha. Initial deposits of 0.120 and 0.164 mg/kg at 15 and 30 g ai/ha treatments dissipated to 0.011 and 0.014 mg/kg in 10 days after the third application with a half life of 2.92 and 2.86 days. The residues were degraded below detectable levels (<0.009 mg/kg) in 15 days. As the initial deposits in both the rates were less than MRL, a safe waiting period of 1.0 day was suggested. Washing of okra fruits with tap water removed lambda-cyhalothrin residues to the extent of 40.0-42.7% in 0-day samples and 30.8-33.9% in fifth day samples. Another study by Akhtera *et al.* (2009) evaluated and determined residues of three pesticides in vegetables, belonging to Organophosphate group viz. Triazophos, profenofos and chlorpyriphos which was extensively used in the Southern part of Punjab province in Pakistan on the summer vegetables like: egg plant, pumpkins and okra. Vegetables were analyzed for pesticide residues using multi-residue analysis by High-Performance Liquid Chromatography (HPLC) equipped with UV detector. It was observed that 33.0 per cent of the samples were contaminated with any of the above three pesticides.

Results of the study conducted by Chahal *et al.* (1999) revealed that about 67 per cent of the vegetable samples were contaminated with.

It was thus concluded from are above study that no pesticide residues were found in rice and wheat flour samples. Residues of chlorpyriphos, quinaphos, ethion, triazophos and endosulfan were found in the vegetable samples. All the samples of cauliflower were containing higher chlorpyriphos residue than the prescribed MRL by Codex Standards. Compared to the unorganized retail outlets, sourcing of brinjal and cabbage from the organized retail outlets can be considered as a safer option due to the absence of pesticide residues. About 73 per cent samples of cabbage were contaminated with chlorpyriphos, but the residues levels for these samples were below the recommended MRL. The study reveals that maximum number of pesticides like chlorpyriphos, triazophos, melathion, ethion and endosulfan were found in samples of okra. Chlorpyriphos was found in the all the samples of okra, while 73 per cent of okra samples were contaminated with malathion and endosulfan. Use of these pesticides for okra is not recommended by Codex Alimentarius Commission. This may be attributed to the use of non recommended pesticides on the vegetable crops and is thus an area of concern in context of food safety.

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Potential Carbon Offset in Public Plantation, Tarai, Nepal: Offering Opportunity for REDD+ and Soil Fertility

Ram Asheshwar Mandal, Ishwar Chandra Dutta[1], Pramod Kumar Jha[2] and Samshul Mohammad Haque[3]

Trichandra College, Kathmandu, Nepal [1] Tribhuban University Service Commission, Kirtipur, Kathmandu, Nepal
[2] Central department of botany, Tribhuban university Kirtipur, Kathmandu, Nepal
[3] Institute of Forestry, Hetauda Campus, Nepal
E-mail: ram.mandal@gmail.com

Abstract: Public plantations are managed under agro-forestry system, which is aligned with the purpose of REDD+ reward but it needs sufficient records of carbon. Thus, objectives of the study were to compare the carbon stocks of public plantations with neighboring sites, estimate the variation in mean annual incremental carbon (MAIC) and explore changes in soil C, N, P and K after plantation. Three public plantations of Mahottary, Nepal were selected for study. Altogether twenty eight sample plots were randomly established navigating GPS coordinates in the quadrates of 10mx10m for pole and 1mx1m for litter and grasses. Height and diameter of pole were measured and samples of others were also collected. The soil samples were collected from the centre of the plot from 0-0.1m, 0.1-0.3m and 0.30-0.60m depths. There were significant differences in carbon stocks with 140.32 t ha^{-1} in plantation and 68.39 t ha^{-1} in neighboring site of Shreepur public plantation. The highest value of MAIC was found nearly 10.19 t ha^{-1} while the values of soil C and N were 31.46 t ha^{-1} and 98.41kg ha^{-1} respectively in 0-0.1m and decreased by soil depths in Shreepur site. Same trend was found in soil P and K to all sites.

Key Words: Agroforestry, Mean annual incremental carbon, Plantation, REDD+, Soil fertility,

Managing carbon either by reducing deforestation and forest degradation or by enhancing the tree cover has significant value in REDD+ and it can add high values if plantations are managed by the landless poor communities (Smith and Scherr, 2003, Shively, 2004). The ultimate goals of REDD+ are cut off pressure on the forest either by establishing the plantation, enhancing regeneration or reducing the deforestation and forest degradation. The REDD+ offers to improve the livelihood of the poor communities (Campbell, 2009, Hett *et al.*, 2011). The plantations also create the opportunity of increasing soil fertility, which enables degraded lands to reclaim and yield more from intercrops and generate income for landless communities through agro-forestry practices. Such afforestation activities significantly contribute to sequestrate the CO_2 in biomass and add fertility in soil (Jackson *et al.*, 2002, Hoghton, 1999). South Asia has about 423 million population and about 25 per cent of population lives under the poverty line out of that 80 per cent people are dependent on forest products (Pokharel, 2011). The main reason of deforestation and forest degradation is poverty because of the people's dependency on forest for subsistence livelihood (Bradford *et al.*, 2012). So, it is essential to first manage the forest for dependant poor people to kick out the key causes of deforestation and forest degradation (Willium, 1999). In this circumstance, the REDD+ has also focused to manage the factors like local poverty for enhancing the forest stock in order to reduce emission to meet the global target of keeping the temperature below 2°C in this century (UNFCCC, 2010).

Annually, there is decline in world's forest areas due to heavy pressure of increasing poor populations. The global net change in forest area in the period of 2000–2010 was estimated -5.2 million ha annually but plantation was accounting for 130 million ha by area and 3% of world's forest (Mini and Rao, 2011). Southeast Asia experienced the largest shrink in forest area in the region since last ten years, with an annual net loss of more than 0.9 million hectares. In Nepal, about 84,000 hectares of forest were deforested annually between 1991 and 2001. Out of this, the annual deforestation was nearly ten thousand hectares in Tarai, but there was positive change in forest cover about 0.25% in Mahottary district between 1991 to 2001 (DoF, 2005) improving the forests through community based forest management. However, presently, people realize that there is still increase in deforestation and forest degradation activities.

The public plantations in Nepal are the best example of forest enhancement where landless communities are adopting tree plantations mainly of *Eucalyptus camaldulensis* through agro forestry practice to manage community degraded lands for income generation and collection of grasses, leaf litter, small twigs, etc. and ultimately hoping to gain the high income from pole. The

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immediate resultant impact of these activities will reduce pressure on the natural forests. One more attractive future motivation will be REDD+ reward for forest enhancement, it needs intensive database of carbon stocks for designing the appropriate monitoring reporting and verification (MRV) system and developing reference emission level (REL). The database requires mean annual increment of carbon (MAIC) and CO_2 removal from the atmosphere. Meanwhile, managing degraded lands through such plantations also supports in accumulation of C, N, P and K in soil, which play a vital role in improvement of soil fertility. But, such types of innovative works have not been explored yet. Therefore, the objectives of this research were to compare the carbon stocks of public plantations with neighboring sites, show the variation in mean annual incremental carbon (MAIC) and explore changes in soil C, N, P and K after plantation so that such plantations can secure the candidacy to be eligible under REDD+ reward and know the improvement status of soil nutrients.

MATERIAL AND METHODS

Research site: Three public plantations of Bisbitty, Banauta and Shreepur village development committees of Mahottary district in the central Tarai, Nepal were selected for study (Fig. 1). These study sites were planted with pure *Eucalyptus camaldulensis*. The other natural vegetation in the area included *Cynodon dactylon* and *Mimosa pudica*. These public plantations were established in years in 2006, 2007 and 2008 at Shreepur (10.5 ha), Bisbitty (8.8 ha) and Banauta (7.6 ha) sites respectively and managed by landless poor marginalized communities. The inter-crops were *Lathyrus sativus*, *Aloe vera* and green vegetables like ladies finger, cauliflower and brinjal. Mahottary district is situated at 26° 36' to 28° 10' North and 85° 41' to 85° 57' East. The average annual temperature ranges between 20-45°C and average annual rainfall was 1100-3500 mm.

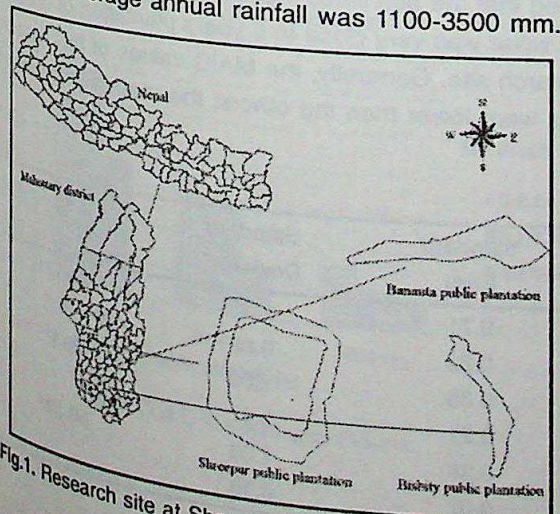


Fig.1. Research site at Shreepur, Banauta and Bisbity VDC, Mahottary district

Sampling design and bio-physical data: Bio-physical data of plantation site were collected from each sample plot. The maps of these plantation areas were prepared using the coordinates taken by Geographical Positioning System (GPS) with the help of ArcGIS software. Simple random sampling was used maintaining one per cent sample intensity (DoF, 2003). Altogether 28 sample plots were randomly identified (9, 11 and 8 sample plots were fixed to collect the data from Banauta, Shreepur and Bisbitty plantation sites, respectively). After that, the centre point coordinates of each sample plots were recorded from the map and uploaded in GPS. Then, nested sample plots were established in the field by navigating the coordinates. The plantations are generally pole sized so sample plots of 10mx10m for poles and saplings while 1mx1m for litter and grasses were established as well as soil samples were fixed in the centre. Height and diameter at breast height (dbh) of poles and sapling (dbh> 5cm) were measured but the samples of sapling (dbh<5cm), grasses, litter and soil were packed to carry out in the laboratory for analysis. Soil samples were collected from three different depths (0-0.1m, 0.1-0.3m and 0.3-0.6m) using soil auger (Wang *et al.*, 1996). The samples of control site were collected from neighboring areas of the plantation site. Thus, five samples of grasses and soil were taken from each site following the same sample size. The control site was only covered by grasses like *Themeda triandra*, *Cynodon dactylon, Mimosa pudica, etc.*.

Data generation: The biophysical data were analyzed applying the simple statistics using Statistical Package of Social Science (SPSS) software. The biomass was calculated using biomass equation of Chave *et al.* (2005) for dbh> 5cm and Tamrakar (2000) for dbh< 5cm but biomass equation of Tamrakar provides only the fresh weight so collected samples were dried in laboratory at 105° until it showed the constant weight. Moreover, samples of litter and grasses were also dried in order to find the dry biomass. Meanwhile the root biomass was calculated multiplying by conversion factor 0.125 of shoot biomass. Then, the biomass was converted into carbon by multiplying with a 0.47 factor (MacDicken, 1997). At the same time soil bulk density and carbon content were determined by using Walkley and Black method. Meanwhile, Nitrogen (N) and Phosphorous (P) were analyzed by Kjeldahl digestion and colorimetry method, respectively, while Potassium (K) was analyzed by using Ammonium acetate extraction method (Mishra *et al.*, 1998) to compare these nutrients between plantation and control sites. The mean annual increment carbon was estimated using following equation and the values wee changed into CO_2 by multiplying with conversion

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factor (44/12) to calculate the CO_2 removal from atmosphere (Lal, 2007).

Mean annual increment of C (MAIC) = (ΣTotal C stock of pole and sapling/Age of plantation)

Data Preparation for statistical analysis: The normality test was done to carry out the further statistical analysis using SPSS 17 software. The identified outliers in data of plantations were removed for further statistical analysis. Then Posthoc Test Homogeneous subset, Tukey and one way ANOVA were applied to test the differences in MAICs among three public plantations. The C stock of plantation site and control sites were also tested after applying t-test to check differences in C stocks of public plantation and control site.

RESULTS AND DISCUSSION

Comparison of C Stocks in Public Plantation and Control Sites: The carbon stock mainly varied in public plantations according to its age. The public plantation of Shreepur site was oldest one so the value of mean C stocks was highest 140.26 t ha^{-1} and the public plantation of Bisbitty site was the youngest one, thus this value was lowest 30.19 t ha^{-1} . The two- sample t-test showed there were significant differences in C stocks in treatment and control sites of all public plantations at 5% level of significance. The mean differences in C stock varied from 51.26 to 66.11 per cent between treatment and control site (Table 1). The estimated value of C stock of biomass was the highest in Shreepur and the lowest in Bisbitty public plantations at the age of 6 and 4 years, respectively. The main reasons of this was number of plants per ha (density), it was highest 3618 individuals ha^{-1} , which showed about 0.039 ton C per tree in Shreepur public plantation. Besides, there was 1756 plants ha^{-1} that indicated nearly 0.035 ton C per tree in Bisbity public plantation, while 2013 individuals ha^{-1} that indicated 0.017 ton C per tree in Banauta. Other reasons may be the age of plants, site quality, effect of intercrops, and activeness of users to carry out the management operations like weeding, cleaning and pruning. No any studies were done on C stocks assessment in public plantation in Nepal however some studies were carried out assessing the C stocks in different plantation sites. The research done by Dutta *et al.* (2012) showed about 84.07 t ha^{-1} and 87.42 t ha^{-1} C of biomass of 10 and 11 years of *Eucalyptus camaldulensis* in Indrakali community forests and in Newardanda Kamidanda community forest of Mahottary district respectively. The value of Shreepur public plantation may be very close after 10 and 11 years.

Annual Increment Carbon (MAIC) in Public Plantations : The values of C stock and MAIC were differed according to the sites of the public plantations. Total carbon stocks of Shreepur, Banauta and Bisbity public plantations were 1473.33, 622.29 and 230.60 tons. Similarly, the value of MAIC was found to be the highest 10.19 t ha^{-1} in Shreepur and it was the lowest 3.39 t ha^{-1} in Bisbitty public plantation. These three public plantations can remove 775.22 ton CO_2 annually from the atmosphere (Table 2). In addition, the Tukey's HSD Post Hoc Test and the one way ANOVA showed that the values of the MAIC of these public plantations were varied at 5% level of significance. The value of MAIC is interrelated with the value of carbon stock, age and number of the plants. As the C stock ha^{-1} was the highest in Shreepur public plantation and the lowest in Bisbitty public plantation, the values of MAIC also differed accordingly. Amatya and Shresth (2002) showed that, the values of MAI of 4 years plantations of poor site was 5.80 m^3 ha^{-1} and 6 years plantation of fair site was 19.40 m^3 ha^{-1}, it means estimated values of MAIC, which is equal to MAI (m^3) x wood density x 0.47 (the wood density of *Eucalyptus Camaldulensis* is 0.96 kg m^{-3}), were 2.63 t ha^{-1} and 8.75 t ha^{-1} respectively and the values were close to the MAIC values of the research sites Bisbity and Banauta plantations. Moreover, Hawkin (1987) stated that the estimated values of MAIC was 11.46 t ha^{-1}, this value was very close to 6 years plantation of Shreepur research site. Generally, the MAIC values of this research sites were lower than the others; the reason being inferior

Table 1. Comparison of C stocks in public plantation

Public plantation	Category	Mean C (t ha^{-1})	% mean difference	Standard Error	Standard Deviation	t_{cal}
Shreepur	Plantation	140.32	51.26	0.71	2.36	96.17*
	Control	68.39		0.23	0.52	
Banauta	Plantation	70.71	66.11	0.38	1.08	20.5*
	Control	23.96		0.21	0.47	
Bisbitty	Plantation	30.34	61.24	0.36	1.03	50.52*
	Control	11.76		0.07	0.15	

*Significant at 5% level of significance

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Table 2. Annual removal of CO_2 from public plantation

Public plantation	Total C (t)	MAIC (t ha^{-1})	MAIC (%)	CO_2 removal (t ha^{-1})	Total annual CO_2 removal (t)
Shreepur	1473.33	10.19	20.00	37.36	392.25
Banauta	622.29	6.56	16.67	24.06	252.65
Bisbitty	230.60	3.39	25.00	12.41	130.32
Total					775.22

soil quality of the present research sites. Growth is better for *Eucalyptus camaldulensis* trees planted on non-saline soil than on moderately saline soil (Dhakal, 2008).

Variation in values of C, N, P and K in soil depth of public plantation

The quantity of C, N, P and K varied with the soil depth and site of public plantation. It was found the highest in 0-0.1m and decreased with soil depths (0.1-0.3m and 0.3-0.6m). The values of soil C were 31.46, 29.39 and 18.28 t ha^{-1} in 0-0.1m, 0.1-0.3m and 0.3-0.6m depths, respectively in Shreepur public plantation. The highest soil C was found in Shreepur public plantation and the lowest in Bisbity plantation (Fig. 2). Likewise, the values of N, P and K were also the highest in Shreepur and the lowest in Bisbity plantation (Fig. 3, 4 and 5). The values of C, N, P and K varied with the soil depth and site quality. The site of Shreepur public plantation was better than other sites; hence there was the highest value of C, N, P and K soil carbon in this site compared to others. The study done by Dutta *et al.* (2012) in Kalidamar community forest, Mahottary showed that the values of soil carbon were 12.88, 12.33 and 11.63 t ha^{-1} in 0-0.1m, 0.1-0.3m and 0.3-0.6m, respectively where values were very close to the present research of Banauta public plantation. In addition, the values of N, P and K in different soil depths were near to similar with the same study.

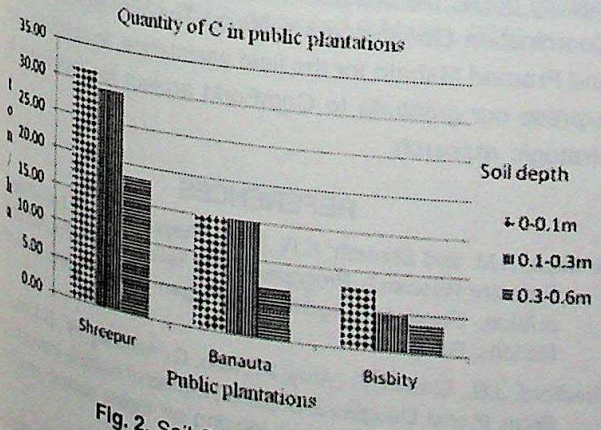


Fig. 2. Soil C in public plantations

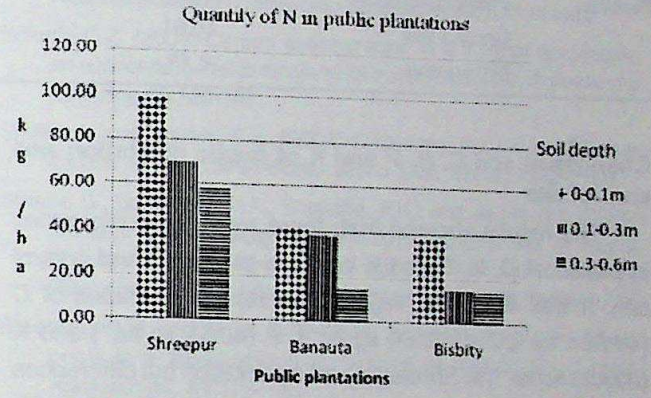


Fig.3. Soil N in public plantations

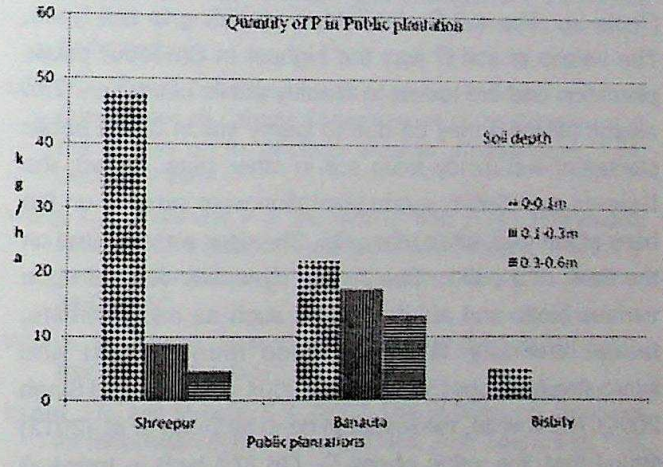


Fig. 4. Soil P in public plantations

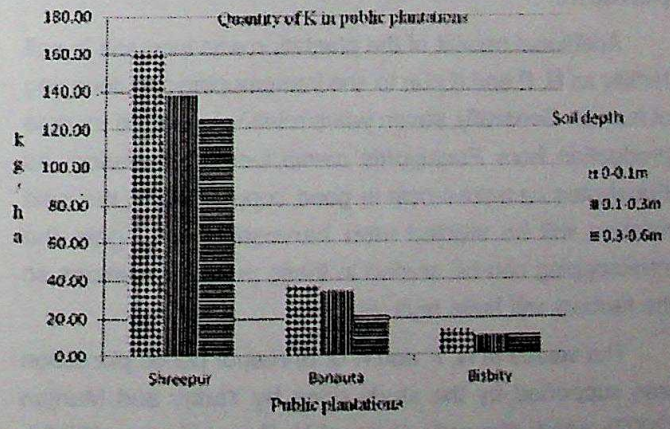


Fig. 5. Soil K in public plantations

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Table 3. C, N, P and K in soil in soil of public plantation and control

Site	Category	Soil C (t ha^{-1})	N(kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Shreepur	Public plantation	79.13	227.23	61.27	426.37
	Control site	29.21	34.33	20.42	123.11
	Difference	49.92	192.90	40.85	303.26
Banauta	Public plantation	37.00	95.47	52.60	94.07
	Control site	22.95	30.22	15.91	28.21
	Difference	14.05	65.25	36.69	65.86
Bisbitty	Public plantation	16.74	67.47	5.20	35.78
	Control site	10.61	19.22	2.01	11.01
	Difference	6.13	48.25	3.19	24.77

Changes in soil C, N, P and K of public plantation and control site

The results showed that, there were high differences in values of C, N, P and K between plantation and control site. It was found the highest differences in values of C (49.92 t ha^{-1}), N (192.90 kg ha^{-1}), P (40.85 kg ha^{-1}) and K (303.26 kg ha^{-1}) in Shreepur public plantation but differences in values of C (6.13 t ha^{-1}), N (48.25 kg ha^{-1}), P (3.19 kg ha^{-1}) and K (24.77 kg ha^{-1}) were lowest in Bisbitty public plantation (Table 3). The soil C also varied according to soil types. The values of soil C was the highest in Shreepur public plantation and the lowest in Bisbitty public plantation. The reason behind it may be due to loamy soil in Shree public plantation and sandy loam soil in other sites. In fact, the Banauta and Bisbitty public plantation were situated on the bank of the river, while other site, Shreepur was situated on the bank of a pond. Soil carbon dynamics depend upon various biotic and abiotic factors such as micro-climate, faunal diversity, land use, land management and intercultivated crops (Sthapit *et al.*, 2004, Shrestha and Singh 2008). Meanwhile, the research done by Dutta *et al.* (2012) stated that, the value of soil C (76.27 t ha^{-1}) in Indrakali community forests was very near to value of Shreepur public plantation.

Additional benefit of the plantation was increase in soil fertility as N, P and K due to the intercropping and decaying of humus. Generally, seven years rotation was fixed for pole production from *Eucalyptus camalduensis* plantation. As *Eucalyptus camaldulensis* is good coppice plant, the next rotation will be started after harvesting and again the intercropping can be carried in these public plantations so the farmers will have high yield.

The values of N, P and K of Shreepur public plantation was supported by the study done by Yadav and Manjan (2007), which showed values of N, P and K were 453.24, 25.46 and 340.62 kg ha^{-1}, respectively of five year plantation of *Leucaena leucocephala* at river side but study done by Paudel and Shah (2003) in sandy loam soil values of P and K in the soil of the pure *Shorea robusta* forest were 76.64 and 267.73 kg ha^{-1}, respectively, these values were not so close to the values of present research. This may be due to variation in properties of the soil (Jackson, 1994).

The present studies indicate that MAIC varied according to the age of fast growing *Eucalyptus camaldulensis* plantations which support to improve the soil fertility like keeping the C, N, P and K in soil, which can play a significant role to generate income of users through intercropping.

Public plantation management has been carried out in nine districts of Tarai, Nepal but assessment of C stock has not done, before. So, it is essential to organize the intensive research works in this field so that they can support to design MRV (measurement, reporting and verification) system and develop REL (referenve emission levels). Another aspect of REDD+ is rewarding for enhancing the forest stocks hence further study should be focused on the potentiality of REDD+ in public plantation management.

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We acknowledge the users of Shreepur, Banauta and Bisbitty public plantations as well as staff of District Forest Coordination Committee Mr. Manoj Thakur, Barun Thakur and Pramod Mahato for the field assistance. In addition, we express our gratitude to ComForM project for financing in strategic research.

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Incorporation of Duckweed (*Spirodela polyrrhiza* L. Schleiden) in Carp Diet - Effect on Water Quality and Fish Productivity

Thokchom Ponil Singh, Meera D. Ansal* and Vaneet Inder Kaur

Department of Aquaculture, College of Fisheries
Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana-141004, Punjab, India
**E-mail: ansalmd@gmail.com*

Abstract: A study was conducted to assess the efficacy of duckweed incorporated diets, containing sundried *Spirodela polyrrhiza* @ 10, 20, 30 and 40% levels, for Indian major carps (*Catla catla* Ham., *Labeo rohita* Ham. and *Cirrhinus mrigala* Ham.) in a semi-intensive poly-culture system. The present study reveals that *Spirodela* inclusion in carp diet did not affect the water quality (pH, dissolved oxygen, total alkalinity, ammonical-nitrogen, nitrite-nitrogen, nitrate-nitrogen and soluble phosphate). Although significant higher growth of fish was supported up to 40% *Spirodela* inclusion level, but maximum growth was recorded at 30% *Spirodela* inclusion level with lowest feed conversion ratio (1.53), resulting in 43.11% higher yield over the control diet. Hence, sundried *Spirodela* can be incorporated in carp diet @ 30% for formulating low cost eco-diets for higher productivity in a poly-culture system.

Key Words: Carp poly-culture, duckweed, non-conventional feed, water quality, fish productivity

Nutrition plays an important role in aquaculture productivity enhancement. Although natural food (plankton) is an integral part of semi-intensive aquaculture, but it is not adequate to support actual growth potential of fish under controlled conditions, hence natural food has to be supplemented with formulated diets. Since supplementary feeding is the major input, costing more than 60% of total the input expenditure in aquaculture, efforts have been made to develop cost effective fish feeds by substituting or replacing the conventional ingredients with some locally available low cost non-conventional feed resources (Dhawan *et al.*, 2004). *Spirodela* (duckweed) based diets have been found to induce higher growth rate in Indian major carps like *Labeo rohita* and *Cirrhinus mrigala* and exotic carp, *Cyprinus carpio* (Ansal *et al.*, 2008; Ansal and Dhawan, 2009). Since carps are cultured in a semi-intensive poly-culture system in India and they contribute more than 85% to the total freshwater aquaculture production of the nation, the present study was conducted to assess efficacy of *Spirodela* based diets with respect to water quality and fish productivity in a semi-intensive carp poly-culture system. *Spirodela* is a fast growing aquatic plant of high nutritive value (with crude protein levels up to 45% on dry matter basis) and digestibility (Robinette *et al.*, 1980, Fasakin, 1999, Leng, 1999), holding great potential for utilization as a non-conventional protein supplement in animal feed including fish.

MATERIAL AND METHODS

The experiment was conducted at the Fish Farm of College of Fisheries, Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana, in 80 square meter (m^2) outdoor cemented tanks in duplicate. A 5cm thick soil layer was spread at the bottom of each tank to hasten the decomposition process. The tube well water was used for filling and maintaining water level in the tanks during the culture period. All the tanks were manured with cow dung @ 20,000 kg ha^{-1} yr^{-1} (160 kg $tank^{-1}year^{-1}$). One fourth (40 kg $tank^{-1}$) of the manure was applied 15 days prior to the stocking of fish and rest in equal fortnight installments (10 kg $tank^{-1}$).

Culture of Duckweed (*Spirodela polyrrhiza* L. Schleiden)

Spirodela was cultured in 4m^2 cemented cisterns in a net house. A 2 cm fine soil layer was spread at the bottom of the cistern. Slurry of 2 kg cow dung (CD) and 1 kg poultry droppings (PD) was spread over the soil layer and water was filled up to 1 m level. One kg fresh inoculum of *S. polyrrhiza* was added after 5 day of manuring. Half of *Spirodela* was harvested every time it covered the whole water surface. Re-manuring was done with 2 kg CD and 1 kg PD slurry every fortnight. Harvested *Spirodela* was sundried and manually powdered for incorporation in different diets.

Preparation of supplementary diets

Five supplementary diets (D_1 - D_5) were prepared with traditionally used basal diet and sundried *Spirodela* in different combinations (Table 1). The proximate analysis of different feed ingredients and prepared diets (crude protein, crude fiber, ether extract, moisture, ash and nitrogen free extract) done on dry matter (DM) basis (Table 2) by following the methods of AOAC (2000).

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Table 1. Composition (%) of different diets

Ingredients	D_1 (control)	D_2	D_3	D_4	D_5
Basal diet*	100	90	80	70	60
Sundried *Spirodela*	-	10	20	30	40

*Basal diet contains rice bran (de-oiled) and mustard meal (de-oiled) in the ratio 1:1.

Stocking and feeding of fish

Fry of Indian major carps viz catla, *Catla catla* (Ham.); rohu, *Labeo rohita* (Ham.) and mrigal, *Cirrhinus mrigala* (Ham.) were stocked in outdoor tanks @ 10,000 ha^{-1} (80 $tank^{-1}$ viz. *catla*-20, *rohu*-35, *mrigal*-25). Fish were fed with different supplementary diets (D_1, D_2, D_3, D_4 and D_5) @ 5% fish body weight (FBW) for the first month, 3 % FBW for the second month and 1.5% FBW for the following five months. Water quality parameters (pH, dissolved oxygen, total alkalinity, ammonical - nitrogen, nitrite – nitrogen, nitrate - nitrogen and soluble phosphates) and growth of fish in terms of net weight gain (NWG) were recorded at monthly intervals following methods of APHA (1991). Food conversion ratio (FCR) for different diets was calculated by formula given below:

$$FCR = \frac{\text{Feed given (g)}}{\text{Average weight gain (g)}}$$

The data was analyzed using "Statgraphics" statistical package. One way ANOVA (Pde 0.05) was applied to work out the effect of different diets on water quality and fish growth.

RESULTS AND DISCUSSION

Water quality

The pH of water ranged from 8.07 - 9.51, in different treatments throughout the culture period and differences among treatments were non-significant (Table 3). The optimum pH for growth and health of most freshwater fish ranges from 6.5 - 9.0 (Boyd and Tucker, 1998). Parmeswaran *et al.* (1971) and Jhingran (1991) have also reported that pH from 6.5 to 9.6 is most suitable for the growth of Indian major carps. The dissolved oxygen (D.O.) content of water ranged between 8.2 - 15.2 mg L^{-1} in different treatment and differences among treatments were non-significant (Table 3). For optimum productivity of carps, D.O. level more than 5.0 mg L^{-1} is required to be maintained in the ponds (Swingle, 1961; Boyd, 1992). The total alkalinity (TA) in different treatment ranged between 93 - 288 mg $CaCO_3$ L^{-1} during the culture period and differences among different treatments were non-significant. Waters with TA less than 50 mg $CaCO_3$ L^{-1} are poorly buffered and less productive. TA between 50 to 300 mg $CaCO_3$ L^{-1} is optimum for carp culture (Boyd and Tucker, 1998).

Ammonical-nitrogen content in the different treatments ranged between 0.030-0.151 mg L^{-1} and the differences among different treatments were non-significant. Fish is very sensitive to unionized ammonia (NH_3) and the optimum aquaculture range is 0.02 – 0.05 mg L^{-1}. Normally in case of high dissolved oxygen concentrations toxicity of ammonia to fish is reduced. In the present study although mean ammonia concentrations in different treatments were little higher than the optimum range, but were within the recommended upper limit of 0.1 mg L^{-1} (Boyd, 1988) and it did not affect survival and growth of fish. Moreover D.O. content in all the treatments was fairly high throughout the experimental period to alleviate ammonia toxicity. Nitrite-nitrogen content in different treatments ranged between 0 - 0.091 mg L^{-1} during the culture period. The differences

Table 2. Percent proximate composition (DM basis) and gross energy of different feed ingredients and diets

Ingredients/diet	Crude protein	Ether extract	Crude fiber	Ash	Nitrogen free extract	Gross energy (Kcal g^{-1})
Rice bran*	14.43	0.98	17.29	10.08	57.23	3.25
Mustard meal *	36.76	1.26	12.76	7.79	41.43	3.89
Sundried *Spirodela*	29.86	2.50	12.97	24.70	29.97	3.15
D_1	25.59	1.12	15.03	8.93	49.33	3.57
D_2	26.01	1.25	14.82	10.51	47.40	3.53
D_3	26.44	1.39	14.60	12.08	45.46	3.49
D_4	26.87	1.53	14.40	13.66	43.53	3.44
D_5	27.28	1.67	14.20	15.24	41.60	3.40

*Solvent extracted

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Table 3. Water quality in the different treatments during the culture period

Parameter	Diets				
	D_1	D_2	D_3	D_4	D_5
pH	8.77[a]	8.69[a]	8.66[a]	8.67[a]	8.68[a]
D.O. (mg L^{-1})	10.85[a]	11.75[a]	11.55[a]	10.95[a]	11.23[a]
Total Alkalinity (mg L^{-1})	205.50[a]	196.0[a]	193.25[a]	187.87[a]	199.75[a]
Ammonical-nitrogen (mg L^{-1})	0.075[a]	0.077[a]	0.065[a]	0.074[a]	0.063[a]
Nitrite-nitrogen (mg L^{-1})	0.019[a]	0.027[a]	0.012[a]	0.004[a]	0.015[a]
Nitrate-nitrogen(mg L^{-1})	0.47[a]	0.49[a]	0.54[a]	0.53[a]	0.55[a]
Soluble phosphate(mg L^{-1})	0.048[a]	0.042[a]	0.043[a]	0.048[a]	0.052[a]

Values are mean of parameters recorded at monthly intervals during the culture period
Values with same superscripts in a row do not differ significantly (Pdd0.05)

among treatments were non-significant and the nitrite-nitrogen content remained much below the recommended levels (< 0.3 mg L^{-1}) for carp culture (Boyd, 1988), in all the treatments. Desirable range of nitrates and soluble phosphate (orthophosphates) for optimum productivity is 0.2 - 1.0 mg L^{-1} and 0.005 - 0.2 mg L^{-1}, respectively (Boyd, 1988). Nitrate-nitrogen and soluble phosphate content in the different treatments ranged between 0.38 to 0.63 mg L^{-1} and 0.004-0.088 mg L^{-1}, during the culture period and differences among treatments were non-significant.

In the present study, all the water quality parameters (pH, D.O., TA, ammonical-nitrogen and nitrite-nitrogen) remained within the desired range for optimum growth of carps, which reveals that *Spirodela* incorporation in carp diet had no undesirable impact on the water quality. Further, nutrient status (nitrate-nitrogen and soluble phosphates) in all the treatments was also well within the recommended range for supporting optimum plankton production throughout the culture period.

Although reports regarding efficacy of *Spirodela* based carp diet with respect to water quality and productivity are lacking, *Lemna* (another duckweed species) based diets, formulated for carps (rohu and common carp) and tilapia (*Oreochromis niloticus*), are reported to have no adverse affect on the water quality (Fasakin et al., 1999, Bairagi *et al.*, 2002, Yilmaz *et al.*, 2004, Tavares *et al.*, 2008, Chowdhury *et al.*, 2008).

Growth and yield of fish

Spirodela incorporated diets did not affect survival of fish in any of the treatment and supported higher weight gain in all the species. Although both *L. rohita* and *C. mrigala* recorded maximum NWG with diets D_4 and *C. catla* recorded maximum NWG with diet D_2, but maximum productivity was recorded with diet D_4 (Table 4). As compared to control diet (D_1), 36.32%, 27.72%, 43.11% and 17.82% higher yield was recorded with diets D_2, D_3, D_4 and D_5, respectively. Diets D_2, D_3 and D_4 recorded better FCR as compared to both control (D_1) and D_5 diets.

Higher growth response of fish fed with *Spirodela* incorporated diets is attributed to their higher nutritive value (Table 2) with respect to higher crude protein, ether extract and ash content and lower nitrogen free extract and crude fiber content as compared to the control diet. Nutritionally duckweeds have been found to substitute soya and fish meal in feeds of farmed animal like chickens, goats, pigs, ducks and fish (Hillman and Culley 1978; Rusoff *et al.*, 1980; Landesman *et al.*, 2002). Earlier Ansal *et al.* (2008) and Ansal and Dhawan (2009) have found that *Spirodela* incorporation in carp diet @ 20% resulted in 20.60, 26.80

Table 4. Comparative growth and yield of fish with different diets

Parameter		Diets				
		D_1	D_2	D_3	D_4	D_5
NWG (gm)	*C. Catla*	79.64	120.63	106.15	102.34	73.44
	L. rohita	87.14	102.85	97.06	122.15	104.45
	C. mrigala	65.42	96.10	95.73	111.54	97.22
Total yield/tank (kg)		6.42	8.75	8.20	9.18	7.56
FCR	1.69	1.53	1.56	1.53	1.75	
Feed cost (Rs) kg^{-1}*		8.50	7.65	6.80	5.95	5.10
Increase in yield over control (%)		—	36.32	27.72	43.11	17.82

*Feed cost calculated as per prevailing rates of ingredients during the experiment

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and 70% higher growth in rohu (*L. rohita*), mrigal (*C. mrigala*) and common carp (*C. carpio*), respectively. Fasakin *et al.* (1999) developed a low cost diet for tilapia (*O. niloticus*) by 30% inclusion of solar-dried *Spirodela* (as replacement for fishmeal) in the practical diets. The results are also in agreement with the findings of Bairagi *et al.* (2002), who recorded best growth performance in rohu (*L. rohita*) fed with diet containing 30% fermented *Lemna* leaf meal. Das *et al.* (2007) recorded 205% higher weight gain and about 105% higher food conversion in *L. rohita* fed with diets having 20% dried *Lemna* powder. Further, dry *Lemna* has been reported to replace up to 50% of the commercial tilapia feed without any adverse effects on fish performance (Essa 1997; Tavares *et al.*, 2008).

The present study will certainly provide an insight in formulating *Spirodela* based diets for supporting higher productivity of carps under a poly-culture system without affecting the water quality. The *Spirodela* inclusion in carp diet did not affect the water quality in any of the treatment. Although *Spirodela* can be incorporated in carp diet up to 40% inclusion level for higher aquaculture productivity but maximum yield was recorded at 30% inclusion level.

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Groundut Yields as Influenced by Heat Unit Efficiency, Levels of Fertility and Varieties under Different Growing Environment in Hyper Arid Zone of Rajasthan

R. S. Meena and R. S. Yadav

Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi- 2210 05, U.P., India
E-mail: rsmeenaagro@gmail.com

Abstract: A field experiment was conducted during *Kharif* seasons of 2009 and 2010 on effect of four growing environments (20th April, 15th May,9th June and 4th July) and four fertility levels (0,20N:40P_2O_5,30N:60 P_2O_5 and 40N:80 P_2O_5 kg ha^{-1}) on various agronomic traits of two varieties (HNG-10 and TG-37A) of groundnut under semi-arid region of Rajasthan. Semi-spreading variety HNG-10 had yields i.e. pod, kernel, haulm and biological yield were also statistically at par with each other from 20th April to 9th June sowing while days to maturity reduced significantly with delay sowing. Variety TG-37A sown at 4th July had significantly higher yields at 4th July sowing. However, in 9th June sowing had significantly higher heat unit efficiency than all three sowing. Significantly higher yields were recorded in 30 kg N-60 kg P_2O_5 ha^{-1} plots which was statistically at par with 40 kg N-80 kg P_2O_5 ha^{-1}.

Key words: Dates of sowing, Fertility levels, Heat unit, Varieties, Yield.

Groundnut shall continue to be an important oil seed crop for the semi- arid regions if the projected demand of oils and fats has to be mat with sustainability. This calls for a considerable growth in production which has to come mainly from the increase in productivity. Of the several factors responsible for its low productivity, proper date of sowing for varieties of different growth habits and efficient nutrient management are considered as major constraint. In dry land agriculture, farmers have limited choice for sowing time, but in irrigated situation sowing time is one of the most important non- monetary input affecting yield of crops. Time of sowing of groundnut is well documented in other regions (Sardana and Kandhola, 2007). However, in Bikaner region, all the cultivation of groundnut is under irrigated conditions. Groundnut cultivation in Bikaner region was started two decades ago in the command area of Indra Gandhi Nahar Pariyojana (IGNP) and later on it spread to tube well irrigated area of the region. At that time, dust storms were common in the region with minimum vegetation during optimum sowing time of May and June months leading to poor crop establishment due to which the farmers started sowing of groundnut in early summer in the months of April and May for better crop establishment with its harvesting in October-November. This practice is still followed, despite reduction in frequency of dust storms in the region. With increase in the irrigated area the practice of early sowing of groundnut in the area despite reduction in the frequency of hot winds is fast depleting the water table in the majority of the blocks (Anonymous, 2011) and has considerably reduced WUE of canal command area. With reduction in the dust storms limiting crop establishment, and in order to stabiles the fast depleting water table and improve in the WUE of the crop, determining suitable sowing time of groundnut varieties of short and long duration maturity would prove a better strategy of improving WUE and the crop productivity. Several workers (Barik *et al.*, 1998; Kabadagi *et al.*, 2010 and Bala *et al.*, 2011) recommended a starter dose of nitrogen until the crop starts nitrogen fixation at about 30 days stage. In the arid region of Rajasthan some workers (Pareek and Poonia, 2011 and Hossain *et al.*, 2007) reported 60 kg N ha^{-1} along with equal level of phosphorus as the appropriate fertilizer level while others recommended 20 kg N ha^{-1} and 32 kg P_2O_5 ha^{-1} for groundnut. Due to the variation in the optimum fertilizer requirement for groundnut reported by research workers it has also become necessary to determine fertilizer requirement for the crop varieties of different maturity under different sowing time. Therefore, an experiment was conducted to investigate on "Yields as Influence by Heat Unit Efficiency, Levels of Fertility and Varieties of Groundnut under Different Dates of Sowing in Arid Western Zone of India"

MATERIAL AND METHODS

Field experiments were conducted during *Kharif* seasons of 2009 and 2010 at Agronomy Farm, College of Agriculture, Bikaner (Rajasthan) under semi-arid conditions. The soil of the experimental site was loamy sand in texture containing 156.33, 16.05 and 221 kg ha^{-1} available nitrogen, phosphorus and potassium, respectively in 0-30 cm soil depth with pH 8.40 and 0.08 per cent organic carbon content. The experiment was laid out in split plot design with three replications assigning 32 treatments consisting of four date

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of sowing (20th April, 15th May, 9th June and 4th July) and two varieties (HNG-10 and TG-37A) as main plot treatments and four fertility levels of nitrogen and phosphorus application (0,20 N:40 P_2O_5, 30 N:60 P_2O_5 and 40 N:80 P_2O_5 kg ha^{-1}) as sub plot treatments. Nitrogen and phosphorus were applied as per treatment through urea and SSP basally in the furrows just before sowing at a depth of 8-10 cm by "*pora*" method. Row spacing of HNG-10 and TG-37A was 25 cm and 30 cm with 5 cm depth. In addition to rainfall received during the crop season 17 irrigations in HNG-10 and 12 irrigations in TG-37A were given in early sowing through sprinkler system from time to time to ensure optimum growth, development and yield of groundnut. Hand weeding was done manually with the help of hand hoe to keep the field weed free. At the time of second weeding earthing up along the rows was also done for improvement in pegging. In case of HNG-10 delayed sowing of this variety from 20th April to 4th July reduction in harvesting time while TG-37A all sowing dates took similar harvesting time.

RESULTS AND DISCUSSION

Effect of sowing dates and varieties

Dates of sowing had significant interaction effects with crop varieties on pod, kernel, haulm and biological yields of groundnut (Table 2). The variety HNG-10 recorded higher and almost similar pod and kernel yields under the first three sowing dates beginning from 20th April to 9th June. Delayed sowing of this variety beyond 9th June resulted in significant reduction in these yields. On the contrary variety TG-37A recorded the lowest yields under the early sowing date of 20th April and enhanced these yields considerably with every delay in sowing and recorded the highest pod and kernel yields at the last sowing date of 4th July. These results of this study could be ascribed to the interaction effect of the genetic constitution of these varieties with the variation in environmental factors as offered by different sowing dates.

Sowing date at 9th June recorded significantly heat unite efficiency (Table 1 and 3) than all other three sowing dates. Significantly higher heat unite efficiency was observed in variety HNG-10 compared to TG-37A. Significantly higher days to maturity was observed in HNG-10 variety compared to TG-37A. The variety HNG-10 being of semi-spreading type, relatively of longer duration and indeterminate growth habit had an optimum maturity duration of 135 to 140 days recorded similar yields under the first three dates with varying maturity periods of 138 to 188 days. The similar yields of this variety recorded under these dates could be

Table 1. Effect of different growing environments, varieties and fertility levels on heat unit efficiency of yields and days to maturity of groundnut

Treatments	Heat unit efficiency (kg ha^{-1} degree-day^{-1})						Days to maturity		
	Biological yield			Pod yield					
	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled
Date of Sowing									
20th April	2.31	1.73	2.02	0.72	0.59	0.65	158	150	154
15th May	2.59	1.67	2.13	0.85	0.71	0.78	144	138	141
09th June	2.84	2.12	2.48	1.00	0.96	0.98	133	125	129
04th July	2.33	1.81	2.07	1.01	0.85	0.93	119	120	119
S.Em±	0.02	0.03	0.02	0.02	0.02	0.02	0.11	0.17	0.10
CD (p=0.05)	0.06	0.08	0.05	0.07	0.07	0.04	0.33	0.52	0.29
Varieties									
HNG-10	3.03	2.20	2.61	1.07	0.87	0.97	157	146	152
TG37-A	2.01	1.46	1.73	0.72	0.68	0.70	119	120	120
S.Em±	0.02	0.02	0.01	0.02	0.02	0.01	0.08	0.12	0.07
CD (p=0.05)	0.05	0.06	0.04	0.05	0.05	0.03	0.23	0.37	0.21
Fertility levels									
Control	2.27	1.66	1.97	0.79	0.69	0.74	138	133	136
20kgN-40 kg P_2O_5 ha^{-1}	2.48	1.81	2.15	0.91	0.79	0.85	138	133	136
30kgN-60 kg P_2O_5 ha^{-1}	2.64	1.93	2.28	0.95	0.83	0.89	138	133	136
40kgN-60 kg P_2O_5 ha^{-1}	2.68	1.92	2.30	0.93	0.80	0.87	138	133	136
S.Em±	0.03	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.01
CD (p=0.05)	0.08	0.06	0.05	0.04	0.04	0.03	NS	NS	NS

NS-Non significant

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Table 2. Effect of different growing environments and fertility levels on yields of groundnut

Treatments	Pod yield (q ha^{-1})			Kernel yield (q ha^{-1})			Haulm yield (q ha^{-1})			Biological yield (q ha^{-1})		
	2009	2010	Pooled	2009	2010	Pooled	2009	2010	pooled	2009	2010	Pooled
Date of Sowing												
20th April	32.91	26.52	29.71	21.25	16.57	18.91	73.21	51.32	62.27	106.12	77.84	91.98
15th May	33.92	27.77	30.84	21.99	17.24	19.62	69.44	37.20	53.32	103.36	64.97	84.16
09th June	33.32	31.30	32.31	21.87	20.14	21.00	61.44	37.39	49.42	94.77	68.69	81.73
04th July	36.86	30.03	33.44	23.45	19.05	21.25	48.09	33.72	40.90	84.94	63.75	74.34
SEm	0.79	0.80	0.56	0.50	0.55	0.37	1.00	0.75	0.63	0.80	1.07	0.67
CD (p=0.05)	2.39	2.41	1.62	1.52	1.66	1.07	3.05	2.27	1.81	2.42	3.24	1.93
Varieties												
HNG-10	41.17	32.57	36.87	26.33	20.21	23.27	76.13	50.39	63.26	117.30	82.97	100.13
TG37-A	27.34	25.23	26.28	17.96	16.29	17.12	49.96	29.42	39.69	77.29	54.65	65.97
SEm	0.56	0.56	0.40	0.35	0.39	0.26	0.71	0.53	0.44	0.56	0.75	0.47
CD (p=0.05)	1.69	1.71	1.15	1.08	1.17	0.76	2.15	1.60	1.28	1.71	2.29	1.36
Fertility												
Control	30.42	25.6	28.04	19.04	15.80	17.42	57.24	36.98	47.11	87.66	62.64	75.15
20kgN-40 kg P_2O_5 ha^{-1}	34.75	29.2	32.00	22.33	18.38	20.35	61.23	38.77	50.00	95.98	68.02	82.00
30kgN-60 kg P_2O_5 ha^{-1}	36.16	30.9	33.53	23.73	19.68	21.70	65.82	41.48	53.65	101.98	72.38	87.18
40kgN-80 kg P_2O_5 ha^{-1}	35.67	29.8	32.74	23.47	19.14	21.31	67.89	42.40	55.15	103.56	72.21	87.89
SEm	0.48	0.57	0.37	0.33	0.37	0.25	0.91	0.67	0.56	1.05	0.87	0.68
CD (p=0.05)	1.37	1.63	1.05	0.94	1.06	0.70	2.58	1.90	1.58	2.98	2.46	1.91

Table 3. Interaction effect of different growing environments and varieties on heat unit efficiency of yields and days to maturity (Pooled Mean)

Treatments	Heat unit efficiency (kg ha^{-1} degree-day^{-1})						Days to maturity		
	Biological yield			Pod yield					
	HNG-10	TG-37A	Mean	HNG-10	TG-37A	Mean	HNG-10	TG-37A	Mean
Date of Sowing									
20th April	2.55	1.49	2.02	0.83	0.48	0.65	187.67	120.00	153.83
15th May	2.60	1.65	2.13	0.95	0.61	0.78	162.17	119.63	140.90
09th June	3.04	1.92	2.48	1.15	0.81	0.98	137.50	120.13	128.81
04th July	2.26	1.88	2.07	0.96	0.90	0.93	119.50	119.00	119.25
Mean	2.61	1.73		0.97	0.70		151.71	119.69	
S.Em±		0.025			0.022			0.144	
CD (p=0.05)		0.07			0.06			0.42	

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attributed to the optimum maturity period available to the crop under the sowing date of 9th June and adjustment of phenological phases as per longer duration of maturity beyond 138 days available under the early sowing dates of 20th April and 15th May due to its indeterminate growth habit. Further delay in sowing of this variety on 4th July provided a considerably lower duration of maturity than optimum and resulted in significant reduction in these yields. On the contrary, the spanish bunch variety TG-37A seem to be of determinate growth habit recorded the lowest mean yield of 21.70q ha^{-1} under the sowing date of 20th April. The yields of this variety progressively and significantly increased under later dates of sowing with the highest yields recorded under the last sowing date of 4th July. Since this is a short duration variety of determinate growth habit, it recorded the highest yields in the last date of sowing as this sowing date provided optimum maturity period requirement to this variety. The early sowing dates provided very longer than optimum periods and harsh environments to this variety of determinate growth habit, these dates recorded significantly lower yields. Since the pod and kernel are cumulative function of the yield attributes, the variation in pod and kernel yields of these varieties as affected by sowing dates recoded in this study could be ascribed to the similar variation in the yields as evidenced from (Table 1) These results are also enclose agreement with the findings of Gochar (2011), Hariprasanna *et al.* (2008) Canver and Kayanak *et al.*(2008). In HNG-10 recorded higher yields than TG-37A.This may be due to HNG-10 variety produced higher to biomass compared to TG-37A, the variety HNG-10 being of semi-spreading type, relatively of longer duration and indeterminate growth habit and took for maturity periods up to 188 days while On the contrary, the spanish bunch variety TG-37A seem to be of determinate growth habit recorded and took for maturity 120 days and yields.

Effect of fertility levels

Fertility levels of nitrogen and phosphorus upto 30 kg N-60 kg P_2O_5 ha^{-1} significantly increased yields i.e. pod yield, kernel yield, haulm yield biological yield and heat unite efficiency (Table 1, 2, 3 and 4) over control and 20 kg N-40 kg P_2O_5 ha^{-1}. Further increase the fertility level up 40 kg N-80 kg P_2O_5 ha^{-1} was statistically at par with 30 kg N-60 kg P_2O_5 ha^{-1}. Days to maturity not affected by fertility levels.Early and plentiful availability of nitrogen and phosphorus to plants favourably influenced the kernel development and kernel size, which ultimately resulted in, increased pod and seed index and shelling percentage. Improved overall growth and profuse branching due to nitrogen and phosphorus fertilization led to increased net photosynthesis on one hand

Table 4. Interaction effect of different growing environments and varieties on yields of groundnut (Pooled Mean)

Treatments	Pod yield (q ha^{-1})			Kernel yield (q ha^{-1})			Haulm yield (q ha^{-1})			Biological yield (q ha^{-1})		
	HNG-10	TG-37A	Mean	HNG-10	TG-37A	Mean	HNG-10	TG-37A	Mean	HNG-10	TG-37A	Mean
Date of Sowing												
20th April	37.73	21.70	29.71	23.65	14.16	18.91	78.30	46.23	62.27	116.03	67.93	91.98
15th May	37.42	24.26	30.84	23.46	15.78	19.62	65.63	41.01	53.32	103.05	65.27	84.16
09th June	37.89	26.73	32.31	24.44	17.56	21.00	62.38	36.46	49.42	100.27	63.19	81.73
04th July	34.44	32.44	33.44	21.51	20.99	21.25	46.74	35.06	40.90	81.18	67.51	74.34
Mean	36.87	26.28		23.27	17.12		63.26	39.69		100.13	65.97	
S.Em±		0.792			0.524			0.885			0.942	
CD (p=0.05)		2.30			1.52			2.56			2.73	

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and greater mobilization of photosynthates towards reproductive structures on the other might have increased the yields significantly result are agreement with those of (Kanwar *et al.* (1983) and Parasuraman *et al.* (1998)

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Indian Journal of Ecology

Influence of Plant Densities on Insect Pests Incidence and Yield in Direct Seeded Rice (*Oryza sativa* L.)

Simerjeet Kaur[1], Surjit Singh[1], K.S. Suri[2] and S.S. Walia[1]

[1]Department of Agronomy [2]Department of Entomology
Punjab Agricultural University, Ludhiana-141004, Punjab, India
E-mail: simer_abh@yahoo.com

Abstract: Field experiments were conducted during *kharif* 2009-10 to study the effect of seed rate (20 kg, 30 kg, 40 kg and 50 kg ha^{-1}) and row spacing (15, 20, 25 and 30 cm) on insect-pest incidence and grain yield of dry-drilled direct seeded rice. The seed rates and row spacings did not have any significant effect on crop dry matter accumulation, effective tillers and grain yield. Stem borer and leaf folder damage was the maximum with seed rate of 50 kg which was significantly more as compared with seed rate of 20 kg and 30 kg ha^{-1} and was statistically similar to damage observed with seed rate of 40 kg ha^{-1}. Stem borer damage was significantly more at narrow row spacing of 15 cm as compared to wider row spacings of 25 and 30 cm but it was statistically at par with stem borer damage reported in 20 cm row spacing. Leaf folder damage was also significantly more at narrow row spacing of 15 cm as compared to wider row spacings of 20, 25 and 30 cm. Thus at higher plant densities, damage due to stem borer and leaf folder was more in dry-drilled direct seeded rice.

Key Words: Direct Seeded Rice, Leaf Folder, Stem borer, Seed Rate, Row Spacing

Rice is the most important cereal crop and is the staple diet of 70 per cent of the world's population. Due to receding water table, rising costs of labour for transplanting of paddy and adverse effects of puddling on soil health; direct seeded rice (DSR) is gaining popularity. The effect of plant density on insect pest abundance is varied and complex. Dense plantings change crop growth, development, and microclimate, which in turn have an effect on pests and their natural enemies. More insect damage in higher plant population may be attributed to overcrowding which results to high competition, exhaustion of available soil nutrient and reduction in biochemical activities and change in micro-environment (Ihejirika *et. al.*, 2008). Sparse planting encourages weeds and indirectly has an effect on insect abundance. Low tiller numbers per unit area can result in a higher percentage of tillers damaged by stem borers. On the other hand, closely spaced plants shade each other, making rice plants more vulnerable to brown plant hopper due to increased humidity, greater plant surface area for oviposition, and less crowded feeding conditions. Dense planting increases populations of plant hoppers, leaf hoppers, leaf folders, gall midges, black bugs, and caseworms while whorl maggots, root aphids, root weevils and leaf beetles may become less abundant (Litsinger 1994). Amongst insect pests causing severe damage to rice crop in Punjab, stem borers viz. *Scirpophaga incertulas* (Walker); *S. innotata* (Walker); *Sesamia inferens* (Walker) and leaf folder, *Cnaphalocrocis medinalis* (Guenee) are the dominating ones. There is scanty information available on the effect of plant densities on insect pest incidence in direct seeded rice. So, the present study was carried out to study the influence of different seed rates and row spacing on insect pest incidence and grain yield of dry-drilled direct seeded rice.

MATERIAL AND METHODS

The experiment was conducted at Students' Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (Punjab) during *kharif* seasons of 2009 and 2010 to study the effect of seed rate and row spacing on insect pest incidence and grain yield of direct seeded rice. It contained 16 combinations of 4 seed rates (20 kg, 30 kg, 40 kg and 50 kg ha^{-1}) and 4 row to row spacings (15, 20, 25 and 30 cm). Experiment was laid out in Randomised Block Design with 3 replications. The soil of the experimental site was loamy sand in texture with normal soil reaction & electrical conductivity, low in organic carbon and available nitrogen and medium in available phosphorus and potassium. Sowing of rice cv. PAU 201 was done on 6th June and 4th June using primed seed after seed treatment on fine seed-bed with single row seed drill as per seed rate and row spacing treatments during 2009 and 2010, respectively. Recommended package of practice was followed for raising crop.

The number of seedlings emerged were counted at 15 days after sowing (DAS) from five randomly selected places in each plot from 50 cm × 50 cm area. Finally, counted plant population was expressed as number of seedlings m^{-2}. Dry matter accumulation by the crop was recorded using plant destructive method from 25 cm × 25 cm area. The

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collected plant biomass was first sun dried and then oven dried at 60°C till constant weight and it was expressed as g m^{-2}. The number of effective tillers (panicle bearing tillers) was counted at harvest from plants of 50 cm × 50 cm area from each plot. Count was finally expressed as number of effective tillers m^{-2}. The leaf was considered to be damaged by the leaf folder if at least 1/3rd of its area was showing symptoms. Leaf damage was recorded from 5 hills selected at random in each plot at regular interval starting from 60 DAS and at harvest. The observations for total number of leaves per hill and damaged leaves were recorded and per cent damage was worked out. Similarly, observations on stem borer damage (dead heart and white ear) were recorded and per cent damage was also worked out.

To prevent economic damage to rice crop, a spray of monocrotophos 0.504 kg ai ha^{-1} and a spray of chlorpyriphos 0.50 kg ai ha^{-1} was done on 15th August and 25th September during the first year and on 14th August and 22nd September during the second year, respectively to control stem borer and leaf folder. The crop was harvested manually on October 26-27, 2009 during the first year and on October 24-25, 2010 in the second year from the net plot area. The number of rows harvested was 16, 12, 9 and 8 for 15 cm, 20 cm, 25 cm and 30 cm row spacing, respectively. Harvested produce from the net plot was threshed manually and grain yield recorded in kg. It was then converted to q ha^{-1} at 14 per cent moisture content. The data collected on various parameters under study were pooled for two years and were statistically analyzed.

RESULTS AND DISCUSSION

Growth Parameters and Grain Yield

The difference in emergence of seedlings was significant under the influence of different seed rates (Table 1). Emergence count at 15 DAS was the maximum (199.46 m^{-2}) with seed rate of 50 kg ha^{-1} which was significantly more as compared with other seed rates viz; 20 kg, 30 kg and 40 kg ha^{-1}. The effect of different row to row spacings on emergence count was non-significant. Payman and Singh (2008) also reported the similar findings. The effect of different seed rates and spacings on dry matter accumulation by the crop at harvest was non-significant. The number of effective tillers was not influenced statistically by different seed rates and row to row spacings.

The effect of different seed rates and row to row spacings was non-significant on the grain yield (Table 1). Although the differences were non-significant but numerically, an increasing trend of grain yield was observed with each increase in seed rate suggesting that direct seeded rice can be drilled with lower seed rate without any yield losses under weed-free conditions to save the cost of vital input (seed). Payman and Singh (2008) also reported that increasing seed rate from 40 kg to 60 kg ha^{-1} did not influence the grain yield significantly. Chauhan *et al.* (2011) and Zhao *et al.* (2007) also reported that under weed-free conditions, grain yield were not influenced by the seed rates within the range of 15 kg to 125 kg ha^{-1}. In case of row to row spacings, no significant difference in grain yield was observed. Numerically, the lowest grain yield was obtained with wider row spacing of 30 cm as compared with narrow

Table 1. Effect of seed rates and row to row spacings on emergence count, crop dry matter accumulation, effective tillers and grain yield of direct seeded rice (mean data of two years).

Treatments	Emergence count m^{-2}	Crop dry matter accumulation (g m^{-2}) at harvest	Effective tillers m^{-2}	Grain yield (q ha^{-1})
Seed rate (kg ha^{-1})				
20	100.92	1586.05	312.25	53.81
30	125.42	1622.43	314.25	54.88
40	165.75	1675.91	320.35	55.38
50	199.46	1747.16	322.16	57.14
CD (p=0.05)	14.68	NS	NS	NS
Row to row spacing (cm)				
15	155.42	1646.40	311.12	57.79
20	151.54	1652.28	313.58	55.74
25	145.71	1652.22	321.27	54.50
30	138.88	1680.65	323.04	53.18
CD (p=0.05)	NS	NS	NS	NS

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Table 2. Effect of seed rates and row to row spacings on stem borer damage at 60, 90, 120 DAS and at harvest in direct seeded rice (mean data of two years)

Treatments	60 DAS	90 DAS	120 DAS	At harvest
Seed rate (kg ha^{-1})				
20	7.09 (3.55)	1.89	2.12	0.62
30	8.77 (3.71)	2.00	2.17	0.64
40	9.45 (3.88)	2.06	2.26	0.68
50	10.34 (4.03)	2.26	2.35	0.70
C.D. (p=0.05)	(0.24)	NS	NS	NS
Row to row spacing (cm)				
15	11.45 (4.03)	2.22	2.31	0.75
20	9.33 (3.88)	2.09	2.21	0.67
25	8.39 (3.72)	2.02	2.24	0.63
30	6.49 (3.56)	1.87	2.14	0.59
C.D. (p=0.05)	(0.24)	NS	NS	NS

The data was square root transformed and values in the parenthesis are transformed values.

row spacings although the differences were non-significant, suggesting that direct seeded rice can be drilled at 15 cm to 30 cm without any yield losses under weed-free conditions. Lampayan *et al.* (2010) also reported that the grain yields were similar for row spacings ranging from 25 to 35 cm, whereas, Chauhan and Johnson (2011) reported that aerobic rice grown in 30 cm rows had greater weed biomass and less grain yield as compared to that in 15 cm and 10-20-10 cm paired rows. They further reported that rice crop sown in wider spacing were vulnerable to weed competition for the longest period (49 days) as compared with narrower spacing (39 days).

Insect Pest Incidence

The stem borer damage was significantly affected by different seed rates at 60 DAS during both the years (Table 2). Stem borer damage was the maximum (10.34 %) with seed rate of 50 kg ha^{-1} which was significantly more as compared with seed rate of 20 kg and 30 kg ha^{-1} but was statistically similar to those observed with seed rate of 40 kg ha^{-1}. Likewise, stem borer damage was significantly influenced by different row to row spacings at 60 DAS. Damage was significantly more at narrow row spacing of 15 cm (11.45 %) as compared with wider row spacings of 25 cm and 30 cm but it was statistically at par with stem borer damage reported in 20 cm row spacing. However, stem borer damage was not affected significantly by different seed rates and row to row spacings in the later observations at 90, 120 DAS and at harvest.

The leaf folder damage was significantly affected by different seed rates at 60 DAS (Table 3). Leaf folder damage was the maximum (15.30%) with seed rate of 50 kg ha^{-1} which was significantly more as compared with seed rate of 20 kg and 30 kg ha^{-1} but was statistically similar to those observed with seed rate of 40 kg ha^{-1}. Leaf folder damage

Table 3. Effect of seed rates and row to row spacings on leaf folder damage at 60, 90, 120 DAS and at harvest in direct seeded rice (mean data of two years)

Treatments	60 DAS	90 DAS	120 DAS	At harvest
Seed rate (kg ha^{-1})				
20	11.76 (2.79)	0.75	0.67	1.74
30	12.82 (3.11)	0.86	0.79	1.95
40	14.14 (3.21)	0.91	0.84	2.05
50	15.30 (3.35)	0.93	0.87	2.08
C.D. (p=0.05)	(0.19)	NS	NS	NS
Row to row spacing (cm)				
15	15.25 (3.51)	0.92	0.85	2.06
20	14.14 (3.20)	0.90	0.77	2.02
25	12.86 (3.05)	0.86	0.81	1.96
30	11.77 (2.71)	0.77	0.74	1.77
C.D. (p=0.05)	(0.19)	NS	NS	NS

The data was square root transformed and values in the parenthesis are transformed values.

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was also significantly influenced by different row to row spacings at 60 DAS (Table 3). Damage was significantly more at narrow row spacing of 15 cm (15.25 %) as compared with wider row spacings of 20, 25 and 30 cm but damage was statistically similar with 20 cm and 25 cm row spacing. The effect of different seed rates and row to row spacings on periodic leaf folder damage was non-significant at later observations (Table 3). The interaction effects of seed rate and row spacing on stem borer and leaf folder damage was non-significant at all periodical growth stages.

Sarao (2007) reported that dead heart and white ear infestation and leaf folder was more in closer spacing (15 cm × 15 cm) as compared with 20 cm × 15 cm, 20 cm × 20 cm and 25 cm × 15 cm in unsprayed crop. However, Shera (2000) reported that different plant spacings (15, 20 and 25 cm) have no effect on dead heart and white ear infestation. Khushwaha and Sharma (1981) reported leaf folder damage of 0.60, 2.60 and 5.60 per cent at three spacings of 20 cm × 15 cm, 15 cm × 15 cm and 10 cm × 10 cm, respectively.

From the above study, it can be concluded that no significant difference in grain yield was observed due to seed rate and row spacing in direct seeded rice but damage due to stem borer and leaf folder was significantly more at narrow row spacing of 15 cm and with seed rate of 50 kg ha^{-1} i.e. at higher plant densities.

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Indian Journal of Ecology

Assessing Heavy Metal Pollution in Agricultural Soil in Pune, Maharashtra, India

Azam Sadat Delbari[1] and D. K. Kulkarni[2]*

[1]*Department of Environmental Science, Pune University, Pune-411 007, India*
[2] *BAIF Development Research Foundation, Warje-Malwadi, Pune- 411 058, India*
**E-mail: dilipkkulkarni@gmail.com*

Abstract: The vehicular pollution around Pune is increasing day by day and naturally it affects agriculture. Present research was conducted to study seasonal variations and different concentrations of the heavy metals - Cr, Cu, Fe, Mn, Ni, Pb and Zn - in agriculture near the highways in six locations investigated during two major seasons. Soil samples were collected during 2009-2010 in dry and wet (summer and monsoon) seasons and were treated and digested using standard wet digestion methods. Heavy metals were determined with Atomic Absorption Spectrophotometer (AAS). Level of heavy metals concentrations is below normal range.

Key Words: Agricultural Soils, Heavy Metal Pollution, Pune-Maharashtra.

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Heavy metals are primarily deposited due to the wastes on the soil and agricultural inputs like animal manure (Xue *et. al.*, 2003); mineral fertilizer (Gray *et al.*, 1999); sewage sludge (Cornus, 2001) or diffuse contamination via aerosol deposition on the soil surface (Hernandez *et al.*, 2003). Several heavy metals (e.g. Cd, Cr, Pb and Ni) which are potentially harmful for human health and ecosystem can be provided by the fertilizers (Mortvedt, 1982). Irrigation water, pesticides and amendments (e.g. sewage sledges, compost) are other important sources of heavy metal in soils (Webber, 1981). Pollution studies are essential to have a good knowledge of the content and variability of heavy metals in the soil.

The drastic increase in number of vehicles have resulted in a significant increase in the emission load of various pollutants. The quantum of vehicular pollutants emitted is highest in cities like Delhi, Mumbai, Bangalore, Calcutta and Ahmadabad. The daily pollution load generated due to automobiles is higher. Cadmium, (Cd), Lead (Pb), Copper (Cu) and Zinc (Zn) and fuel additives that are released into the atmosphere and deposited in to the soil. High concentrations of heavy metals occur within 100 m of major highways road and near urban centres directly impacting on surrounding soils (Gigliotti *et al.*, 1996). Udom *et al.* (1976) assessed the values of the vehicular heavy metals like Cd, Cr, Cu, P., Ni and Zn through vehicular pollution in soil samples and plants of a suburban highway in the New Zealand. Soil depth is responsible for metal concentrations intensely decreased and pulled the results that much of the deposited metal particles remain in 0-5 cm of roadside surface soil depth. Sonavane *et al.* (2009) conducted seasonal variation of some micronutrient in soil around Kurkumbh area Daund from Pune district. Range of variation in pre-monsoon and post-monsoon concentration of heavy metals from 8 different locations on soil samples were carried out. Heavy metals have become a burning issue in recent years because of their potential accumulation in bio-systems through contaminated water, soil and air. Present work is based on vehicular pollution on agriculture soils around Pune in two seasons namely summer and monsoon.

MATERIAL AND METHODS

Area under study:

Present study has been carried out around Pune at six sites (Map). The cropping pattern and soil collection for heavy metals has been recorded since 2009.



Data Collection and Analysis

It is obsearved that surface soil has heavy impact of vehicular pollution. In this respect, 36 soil samples (6 stations and every station 3 samples 5m, 10m, 15m and opposite site) were collected at surface level (0–10 cm in depth) from various locations to cover industrial, commercial and residential areas. The collected soil samples were air-dried and sieved into coarse and fine fractions. Well-mixed

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The area around Pune was selected for data collection.

Stations No.	Name of station
1	Shivapur Toll collection centre- Pune to Bangalore
2	Bhugaon- Pune to Mangaon-Konkan
3	Telegaon- Chakan- Connecting road to Bombay Pune old highway to Nasik Highway
4	Nasik- Pune highway, Near Hotel Vedant
5	Pune- Ahmednagar Highway- Harshraj Garden Dhaba
6	Pune-Solhapur highway- Near village Yavat.

samples of 2 g each were taken in 250 ml glass beakers and digested with 8 ml of aquilegia a sand bath for 2 hours. After evaporation to near dryness, the samples were dissolved with 10 ml of 2% nitric acid, filtered and then diluted to 50 ml with distilled water. Heavy metal concentrations of each fraction was analyzed by Atomic Absorption Spectrophotometery. Quality assurance was guaranteed through double determinations and use of blanks for correction of background and other sources of error. EC of the soil samples were determined from saturation extract by conductivity meter.

Heavy metal concentration in Agriculture soils along highways

The concentrations of heavy metal Cr, Mn, Fe, Cd, Cu, Pb, Zn and Ni in the agriculture soils of Pune were analyze for two seasons (Summer and Monsoon). Collected sample from various locations were covered industrial, commercial and residential areas since 2009 to 2011.

RESULTS AND DISCUSSION

Chromium (G)

The concentration of G in the agricultural soils at monsoon around Pune ranged from 0.34 to 0.81 ìg/g with the mean value of 0.62 ìg g^{-1} while the concentration of G in the agricultural soils in summer around Pune ranged from 0. 4 to 1.27 ìg g^{-1} with the mean value of 0.81 ìg g^{-1} Fig. 1. Maximum Cr was observed at station three opposite , 1.27ìg g^{-1} at summer and minimum concentration was observed at station one ,0.34 ìg g^{-1} in monsoon season.

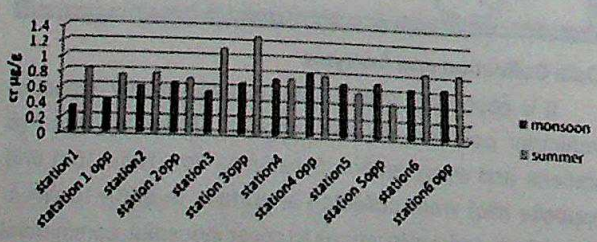


Fig. 1. Concentration of chruimin agriculture soil, Pune, India

Copper (Cu)

In this study the concentration of Cu in soil were in the range of 2.16 -10.33 (ìg kg^{-1}). The Cu content in the agricultural soils around Pune in monsoon ranged from 2.16 to 7.00 ìg g^{-1} with the mean value of 4.03ìg g^{-1} Fig. 2. Also the copper content in the agricultural soils around Pune in summer ranged from 2.60 to 10.33 ìg g^{-1} with the mean value of 5.08 ìg g^{-1} Fig. 2. Maximum Cu concentration was observed at station two opposite, 10.30 ìg g^{-1} Bhugaon-Pune to Mangaon-Konkan while minimum Cu concentration was observed in monsoon at station three 2.16 ìg g^{-1} TalegaonChakan Road.

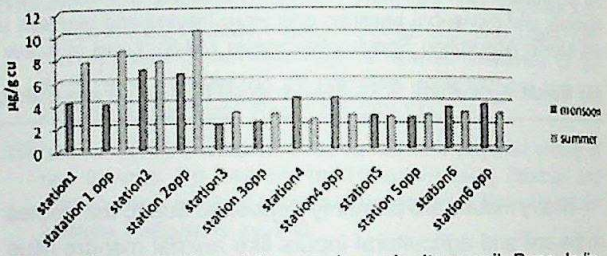


Fig. 2. Concentration of Copper in agriculture soil, Pune, India

Lead (Pb)

Concentration of Pb are in the range of 0.08-0.45 (ìg kg^{-1}).The Pb content in the agricultural soils in monsoon around Pune ranged from 0.08 to 0.23 ìg g^{-1} with the mean value of 0.25 ìg g^{-1} while the Pb content in the agricultural soils around Pune in summer ranged from 0.16 to 0.45ìg g^{-1} with the mean value of 0.27ìg g^{-1} (Fig. 3). Maximum Pb concentration was observed in summer at station one opposite 0.45 ìg g^{-1} (Talegaon Chakan Road) and minimum concentration of Pb was observed in monsoon at station one 0.08 ìg g^{-1} (Shivapur Toll collection centre- Pune to Bangalore).

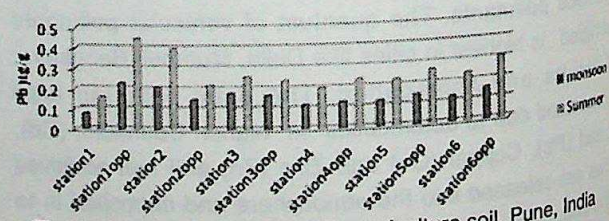


Fig. 3. Concentration of Lead in agriculture soil, Pune, India

Nickel (Ni)

The Ni content in the agricultural soils in monsoon ranged from 0.34 to 0.79 ìg g^{-1} with the mean value of 0.50 ìg g^{-1} in dry season the Nickel content in the agricultural soils in summer ranged from 1.51 to 1.88 ìg g^{-1} with the mean value of 1.70 ìg g^{-1} Fig. 4. Maximum Ni concentration was observed in summer at station three opposite (1.88 ìg g^{-1}) i.e. Telegaon- Chakan- Connecting road to Bombay Pune old highway to Nasik Highway but minimum concentration

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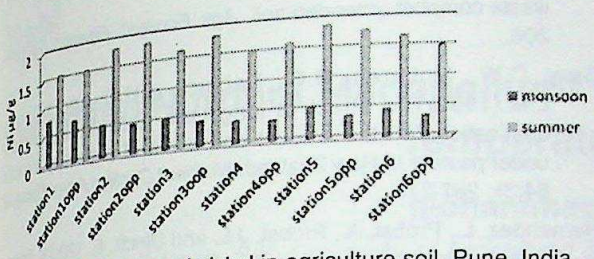


Fig. 4. Concentration of nickel in agriculture soil, Pune, India

was observed in monsoon at station six opposite 0.34 ìg g^{-1}(Pune-Solhapur highway).

Zinc (Zn)

The concentration of Zn are in the range of 0.95 to 4.6ìg g^{-1}.The amount of zinc in the agricultural soils around Pune in monsoon ranged from 0.95 to 3.60 ìg g^{-1} with the mean value of 2.01 ìg g^{-1}. Also in summer the amount of zinc ranged from 1.00 to 4.60 ìg g^{-1} with the mean value of 1.82 ìg g^{-1} Fig. 5. Maximum Zn concentration was observed in summer at station two 4.6 ìg g^{-1} (Bhugaon- Pune to Mangaon-Konkan) whereas minimum zinc concentration was observed in monsoon at station five opposite , 0.56 ìg g^{-1} (Bhugaon-Pune-Mangaon-Konkan).

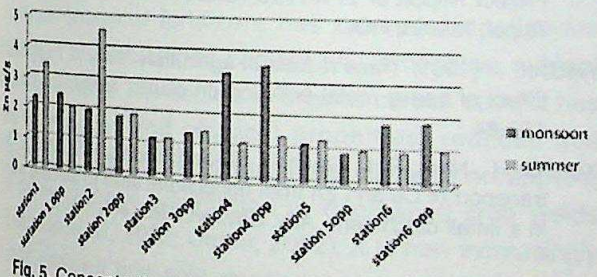


Fig. 5. Concentration of zinc in agriculture soil, Pune, India

Iron (Fe)

In monsoon the Fe content in Pune ranged from 7.33 to 23.33 ìg g^{-1} with the mean value of 13.30 ìg g^{-1}. Fe content in the agricultural soils around Pune in summer ranged from 9.54 to 6.16 ìg g^{-1} with the mean value of 8.00 ìg g^{-1} (Fig. 6).

Maximum Fe was observed at station two opposite (23.33 ìg g^{-1}) in monsoon and minimum Fe was observed at station three (6.16 ìg g^{-1}) in summer .

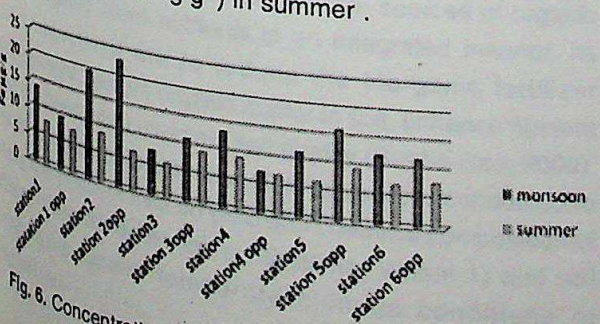


Fig. 6. Concentration of Iron in agriculture soil, Pune, India

Manganese (Mn)

Mn concentration ranged between 27 to 42ìg g^{-1}, with the mean value of 33.5 ìg g^{-1} in monsoon on the other hand Mn concentration in summer ranged between 13.13 to 24.64 ìg g^{-1}, with the mean value of 17.95 ìg g^{-1} (Fig. 7). Maximum Mn concentration was observed in monsoon at station three opposite 42 ìg g^{-1} and minimum concentration was observed in summer at station six opposite, 13.13ìg g^{-1} Pune-Solhapur highway- Near village Yavat.

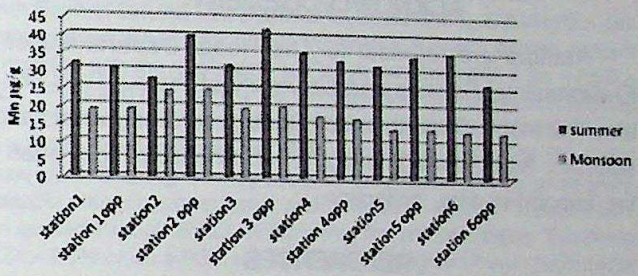


Fig. 7. Concentration Manganese in agriculture soil, Pune, India

In literature, it was observed that as we go away from main highway region the metal concentration in top soil layer goes on decreasing. But in this study, such a decrease in concentration of metals was not observed. At some stations it was showing such trend of decrease in concentrations of metals. And at some stations though we go away from high way on both sides there was no such trend observed but few sites showed increase in concentrations of metals though the distance is more from the high way.

The reasons for more metal concentration in soil are mainly discharge of large quantities of industrial effluent wastes or by products to the environment, excessive fertilizer and pesticide application. Particulate lead from automobile exhaust settles on soil along side of high way with heavy automobile traffic. Metals is natural elements that have been extracted from the earth and harnessed for human use as well as a major category of globally distributed pollutants. It is important to understand metal toxicity of road side soil and vegetation. The effect of pollution can be minimize by plantation of suitable hyper-accumulator plants to rehabilitate contaminated areas and regulate metal emissions effectively.

According to the survey made by Chen (2000) in Tawin in 787 ha of rural soils. The bioavailable concentrations of heavy metals extracted by 0.1 M HC1 in these soils were higher than the critical levels proposed by the government, which were (per kg dry soil) 100 mg kg^{-1} for copper, 10 mg kg^{-1} for cadmium, 16 mg kg^{-1} for chromium, 100 kg mg^{-1} for nickel, 120 kg mg^{-1} for lead, and 80 mg kg^{-1} for zinc. The major trace elements found in these contaminated soils

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were Cd, Cu, Cr, Ni, Pb and Zn. A working group was organized by the government in 1991 to develop guidelines for monitoring sites, and to assess levels of heavy metal in polluted sites (Wang *et al.*, 1994b; Chen *et al.*, 1996). These guidelines are based mainly on soil properties and the effect of heavy metals. In case of India government authorities has not prepared guidelines for heavy metals concentration in soils and crops for each state.

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Integrated Nutrient Management in Wheat (*Triticum aestivum*) under Temperate Himalayas

Mohammad Auyoub Bhat

Division of Soil Science, S.K. University of Agricultural Sciences and Technology of Kashmir, Srinagar-191121, India
E-mail: auyoubbutt@gmail.com

Abstract: Field experiments were conducted at the Agricultural Research Farm of SKUAST-K, Shalimar campus, Srinagar during the rabi seasons 2007-2008 and 2008-2009 to evolve an integrated nutrient management system for wheat. Highest grain yield, protein content in grain and nutrient concentrations in grain and straw of wheat were recorded with the application of Recommended NPK + Zn + PSB + FYM followed by Rec. NPK + Zn + FYM, Rec. NPK + FYM, Rec. NPK + Zn + PSB and Rec. NPK + Zn. On application in conjunction with the recommended dose of NPK, the grain yield increased by 9.5, 13.1, 16.9, 21.9 and 23.6% and straw yield by 10.1, 12.4, 19.6, 24.1 and 23.4%, respectively with Zn, Zn + PSB, FYM, Zn + FYM and Zn + PSB + FYM. The treatment Rec. NPK + FYM was at par with Rec. NPK + Zn + FYM and Rec. NPK + Zn + PSB + FYM for both grain and straw yields and significantly superior over Rec. NPK for grain yield. Application of FYM along with fertilizers increased organic carbon, available nitrogen, phosphorus and potassium and DTPA-extractable zinc levels in the soil. Application of FYM was found to be as good as Zn applied through $ZnSO_4$ in improving the soil zinc status. The study revealed that recommended dose of NPK be supplemented with FYM, Zn + FYM or Zn + PSB + FYM to sustain higher wheat yields under temperate Himalayas.

Key words: Integrated nutrient management, Wheat, Yield, Uptake, Available nutrients.

Intensive cropping with unbalanced use of high analysis chemical fertilizers has caused a continuous decline in organic carbon content and a negative nutrient balance in soils. The decline in organic carbon content has led to impaired soil physical properties, reduced soil biodiversity, aggravation of demand for nutrients not applied, all of which have contributed to decreased crop yields (Bhandari *et al.*, 2002; Carter, 2002). It is now increasingly being realized that sole dependence on chemical input based agriculture is not sustainable in the long run and only integrated nutrient management (INM) involving a combination of chemical fertilizers, organic manures and microbial inoculants is imperative to sustain crop yield and soil health in the long run. This is especially important for developing countries where farming will continue to be in the hands of small and marginal farmers. The basic concept underlying the principle of INM is to maintain or adjust plant nutrient supply to achieve a given level of crop production by optimizing the benefits from all possible sources of organic and inorganic plant nutrients in an integrated manner. Its main objectives are to reduce the inorganic fertilizer requirement, restore organic matter in soil, enhance nutrient use efficiency and maintain soil quality (Subba Rao, 2009). Keeping these points in view, field trials were conducted to study the effect of INM on yield and chemical composition of wheat (*Triticum aestivum*, cv. Shalimar Wheat 1) and soil properties under temperate climatic conditions of Himalayas.

MATERIALS AND METHODS

The present study was undertaken during the winter seasons of 2007-2008 and 2008-2009 at the Agricultural Research Farm of SKUAST-K, Shalimar campus, Srinagar. The soil of the experimental site was clay loam in texture with initial pH 7.0, electrical conductivity 0.1 dS m^{-1}, organic carbon 1.6%, available N, P, K and DTPA-extractable Zn 293, 27, 137 and 2.92 kg ha^{-1}, respectively. The experiment comprising thirteen treatments was laid out in a randomized block design with three replications for each treatment in plots of 5 m X 3 m size. The treatment details were as follows, T_1: Control; T_2: Rec. NPK (Recommended dose of NPK fertilizers); T_3: Rec. NPK + Zn; T_4: Rec. NPK + Zn + PSB (phosphate solubilizing bacteria); T_5: Rec. NPK + FYM (farm yard manure); T_6: Rec. NPK + Zn + FYM; T_7: Rec. NPK + Zn + PSB + FYM; T_8: 50% of Rec. NPK + FYM; T_9: 50% of Rec. NPK + Zn + FYM; T_{10}: 50% of Rec. NPK + Zn + PSB + FYM; T_{11}: 75% of Rec. NPK + FYM and T_{12}: 75% of Rec. NPK + Zn + FYM; T_{13}: 75% of Rec. NPK + Zn + PSB + FYM. Recommended dose of NPK fertilizers based on soil test values was 100 kg N, 80 kg P_2O_5 and 60 kg K_2O ha^{-1}. The chemical composition of FYM (N: 0.42%, P: 0.12%, K: 0.60%,) was determined following the methods adopted by Jackson (1973) and incorporated as per treatments into plots @ 20 tons ha^{-1} fifteen days before sowing of the crop. As per treatments, seeds were soaked in 10% sugar solution containing PSB culture @ 600 g ha^{-1} for about 30 minutes and dried under shade before sowing. As per

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treatments Zn @ 20 kg $ZnSO_4$ ha^{-1} was drilled in the rows of wheat at the time of sowing. The crop was harvested at maturity and the biological yield of each plot was recorded before threshing. After threshing, winnowing and removal of miscellaneous substances, the grain yield acquired from each plot was subtracted from its biological yield to obtain the straw yield. For calculating the harvest index, the grain yield was divided by the biological yield and multiplied by 100. Soil samples (0-22.5 cm) drawn from the experimental field before sowing and after harvest were cleaned, air-dried, ground to pass through a 2 mm stainless steel sieve and analysed for pH and electrical conductivity (EC) in 1:2.5 w/v soil-water suspension (Jackson, 1973). Organic carbon (OC) in soil samples was determined by chromic acid titration method (Walkley and Black, 1934), available nitrogen by alkaline permanganate oxidation method (Subbiah and Asija, 1956), available phosphorus by molybdophosphoric acid blue colour method by extracting with sodium bicarbonate (Olsen *et al.*, 1954), available potassium by flame photometric method (Jackson, 1973) and DTPA-extractable zinc by atomic absorption spectrophotometry after extraction with 0.005 M DTPA (Lindsay and Norvell, 1978). Grain and straw samples collected after harvest were dried at 70ÚC, crushed in a stainless steel grinder and analyzed for nitrogen content by Kjeldahl method (Jackson, 1973). The nitrogen content in grain was multiplied by factor 6.25 to calculate the crude protein content (Nicholas and Nason, 1957). Finely ground plant samples were digested in a mixture of HNO_3-$HClO_4$ (2:1) and in the extract phosphorus was determined by calorimetry, potassium by flame photometry and zinc by atomic absorption spectrophotometry (Jackson, 1973).

RESULTS AND DISCUSSION

Grain and straw yields of wheat: The results presented in Table 1 clearly revealed that all treatment combinations significantly influenced the grain and straw yields of wheat over control. Highest grain yield (46.2 q ha^{-1}) was obtained with the application of Rec. NPK + Zn + PSB + FYM (T_7) and highest straw yield (80.0 q ha^{-1}) with Rec. NPK + Zn + FYM (T_6). Rec. NPK + FYM (T_5) was at par with T_7 and T_6 for both grain and straw yields and significantly superior over Rec. NPK (T_2) for grain yield. Rec. NPK + Zn + PSB (T_4) was at par with T_2 for both grain and straw yields. When applied in combination with the recommended dose of NPK (T_2), the grain yield increased by 9.5, 13.1, 16.9, 21.9 and 23.6% and straw yield by 10.1, 12.4, 19.6, 24.1 and 23.4%, respectively with Zn (T_3), Zn + PSB (T_4), FYM (T_5), Zn + FYM (T_6) and Zn + PSB + FYM (T_7). The increase in grain and straw yields with the application of FYM, PSB and Zn in conjunction with NPK could be assigned to proper nutritional environment for vegetative and reproductive phases of the crop. The results are in agreement with the findings of Jiang *et al.* (2006) and Behera *et al.* (2007). On the basis of harvest index values (Table 1), the performance of the various treatments could be arranged in the order $T_1 < T_{10} < T_9 < T_8 < T_{12} < T_{11} < T_6 < T_5 < T_{13} < T_3 < T_2 < T_7 < T_4$.

Crude protein content in grain: A perusal of the results given in Table 1 revealed that the highest crude protein content in grain (13.2%) was registered with the application of Rec. NPK + Zn + PSB + FYM (T_7) which was significantly superior over Rec. NPK (T_2). Rec. NPK + Zn + FYM (T_6), Rec. NPK + FYM (T_5) and Rec. NPK + Zn + PSB (T_4) were at par with T_7. Enhanced uptake of nitrogen, phosphorus and zinc

Table 1: Effect of INM on grain and straw yields of wheat and protein content in grain (pooled 2007-08 and 2008-09)

Treatment	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest Index (%)	Protein content (%)
T_1: Control	18.3	41.8	30.45	5.9
T_2: Rec. NPK	35.3	60.7	36.77	10.6
T_3: Rec. NPK + Zn	39.0	67.5	36.62	11.5
T_4: Rec. NPK + Zn + PSB	40.6	69.3	36.94	11.8
T_5: Rec. NPK + FYM	42.5	75.5	36.02	12.2
Rec. NPK + Zn + FYM	44.8	80.0	35.9	12.9
T_7: Rec. NPK + Zn + PSB + FYM	46.2	79.2	36.84	13.2
T_8: 50% of Rec. NPK + FYM	26.6	51.7	33.97	7.9
T_9: 50% of Rec. NPK + Zn + FYM	28.4	55.3	33.93	8.6
T_{10}: 50% of Rec. NPK + Zn + PSB + FYM	29.3	57.2	33.87	8.9
T_{11}: 75% of Rec. NPK + FYM	34.2	63.5	35.01	10.4
T_{12}: 75% of Rec. NPK + Zn + FYM	36.7	68.3	34.95	11.1
T_{13}: 75% of Rec. NPK + Zn + PSB + FYM	38.1	66.8	36.32	11.3
CD (P = 0.05)	6.6	15.8	-	1.5

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Table 2: Effect of INM on concentrations and uptake of nutrients by wheat (pooled 2007-08 and 2008-09)

Treatment	Concentration							
	N (%)		P (mg kg^{-1})		K		Zn	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Control	0.94	0.12	0.08	0.05	0.11	1.13	7.3	4.5
T_2: Rec. NPK	1.69	0.28	0.27	0.11	0.24	1.71	16.3	12.7
T_3: Rec. NPK + Zn	1.84	0.31	0.32	0.12	0.26	1.86	21.8	14.6
T_4: Rec. NPK + Zn + PSB	1.88	0.31	0.35	0.12	0.27	1.90	23.3	15.0
T_5: Rec. NPK + FYM	1.95	0.33	0.37	0.12	0.29	1.95	24.1	15.8
Rec. NPK + Zn + FYM	2.06	0.35	0.39	0.13	0.31	2.03	26.8	16.4
T_7: Rec. NPK + Zn + PSB + FYM	2.11	0.35	0.39	0.13	0.31	2.09	28.3	17.0
T_8: 50% of Rec. NPK + FYM	1.27	0.19	0.15	0.08	0.18	1.38	9.5	7.4
T_9: 50% of Rec. NPK + Zn + FYM	1.38	0.22	0.18	0.09	0.20	1.48	11.5	8.8
T_{10}: 50% of Rec. NPK + Zn + PSB + FYM	1.42	0.23	0.20	0.09	0.20	1.50	12.7	9.4
T_{11}: 75% of Rec. NPK + FYM	1.66	0.27	0.25	0.11	0.24	1.68	15.2	11.8
T_{12}: 75% of Rec. NPK + Zn + FYM	1.77	0.30	0.29	0.12	0.25	1.80	19.5	13.5
T_{13}: 75% of Rec. NPK + Zn + PSB + FYM	1.80	0.30	0.30	0.12	0.25	1.84	20.4	13.9
CD (P = 0.05)	0.24	0.07	0.06	0.03	0.06	0.39	6.5	4.2
	Uptake							
	(kg ha^{-1})						(g ha^{-1})	
T_1: Control	17.2	5.0	1.5	2.1	2.0	47.2	13.4	18.8
T_2: Rec. NPK	59.7	17.0	9.5	6.7	8.5	103.8	57.5	77.1
T_3: Rec. NPK + Zn	71.8	20.9	12.5	8.1	10.1	125.6	85.0	98.6
T_4: Rec. NPK + Zn + PSB	76.3	21.5	14.2	8.3	11.0	131.7	94.6	104.0
T_5: Rec. NPK + FYM	82.9	24.9	15.7	9.1	12.3	147.2	102.4	119.3
Rec. NPK + Zn + FYM	92.3	28.0	17.5	10.4	13.9	162.4	120.1	131.2
T_7: Rec. NPK + Zn + PSB + FYM	97.5	27.7	18.0	10.3	14.3	165.5	130.7	134.6
T_8: 50% of Rec. NPK + FYM	33.8	9.8	4.0	4.1	4.8	71.4	25.3	38.3
T_9: 50% of Rec. NPK + Zn + FYM	39.2	12.2	5.1	5.0	5.7	81.8	32.7	48.7
T_{10}: 50% of Rec. NPK + Zn + PSB + FYM	41.6	13.2	5.9	5.2	5.9	85.8	37.2	53.8
T_{11}: 75% of Rec. NPK + FYM	56.8	17.1	8.6	7.0	8.2	106.7	52.0	74.9
T_{12}: 75% of Rec. NPK + Zn + FYM	65.0	20.5	10.6	8.2	9.2	122.9	71.6	92.2
T_{13}: 75% of Rec. NPK + Zn + PSB + FYM	68.6	20	11.4	8.0	9.5	122.9	77.7	92.9
CD (P = 0.05)	1.58	1.11	0.40	0.47	0.40	6.16	4.29	6.64

by crop due to integrated use of FYM, PSB and chemical fertilizers might have favoured the synthesis and conversion of amino acids into proteins in grain (Bhat *et al.*, 2007; Shivakumar and Ahlawat, 2008).

Concentration and uptake of nutrients: It is obvious from the results shown in Table 2 that all treatment combinations brought significant differences in the content and uptake of nutrients by wheat compared to control. The respective concentrations of nitrogen, phosphorus, potassium and zinc increased to a maximum of 2.11%, 0.39%, 0.31% and 28.3 mg kg^{-1} in grain and 0.35%, 0.13%, 2.09% and 17.0 mg kg^{-1} in straw of crop with the application of Rec. NPK + Zn + PSB + FYM (T_7). The tratments Rec. NPK + Zn + FYM (T_6), Rec. NPK + FYM (T_5) and Rec. NPK + Zn + PSB (T_4) were at par with T_7. Maximum uptake of nutrients (grain + straw) by the crop (125.2 kg nitrogen, 28.3 kg phosphorus, 179.8 kg potassium and 265.3 g zinc ha^{-1}) was noticed in T_7 followed by T_6. These were statistically significant in case of both grain and straw compared to other treatments. Higher accumulation and uptake of nutrients could be ascribed to better availability and synergistic effect of applied inorganic and organic sources of nutrients. Similar observations were also made by Bhat *et al.* (2005) and Shivakumar and Ahlawat (2008).

Effect of INM on soil properties: Results pertaining to the effect of INM on properties of the post harvest soil are presented in Table 3. The effect of INM on pH and EC was non-significant. Treatments receiving FYM in combination

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Table 3: Effect of INM on soil properties and available nutrient status (pooled 2007-08 and 2008-09)

Treatment	pH (1:2.5)	EC (dS m^{-1})	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	DTPA-Zn (kg ha^{-1})
T_1: Control	7.0	0.1	1.6	284 :(-9)	27 (+0)	132 (-5)	2.9 (-0.02)
T_2: Rec. NPK	7.0	0.1	1.6	290 (-3)	28 (+1)	135 (-2)	2.9 (-0.02)
T_3: Rec. NPK + Zn	7.0	0.1	1.6	296 (+3)	29 (+2)	138 (+1)	4.8 (+1.9)
T_4: Rec. NPK + Zn + PSB	7.0	0.1	1.6	300 (+7)	29 (+2)	146 (+9)	5.3 (+2.4)
T_5: Rec. NPK + FYM	6.9	0.1	2.2	355 (+62)	36 (+9)	168 (+31)	4.0 (+1.1)
Rec. NPK + Zn + FYM	6.8	0.1	2.2	361 (+68)	36 (+9)	179 (+42)	6.8 (+3.9)
T_7: Rec. NPK + Zn + PSB + FYM	6.8	0.1	2.2	372 (+79)	36 (+9)	183 (+46)	7.5 (+4.6)
T_8: 50% of Rec. NPK + FYM	6.9	0.1	1.9	331 (+38)	31 (+4)	155 (+18)	3.5 (+0.6)
T_9: 50% of Rec. NPK + Zn + FYM	6.8	0.1	1.9	337 (+44)	31 (+4)	158 (+21)	6.2 (+3.3)
T_{10}: 50% of Rec. NPK + Zn + PSB + FYM	6.8	0.1	1.9	344 (+51)	32 (+5)	164 (+27)	6.6 (+3.7)
T_{11}: 75% of Rec. NPK + FYM	6.9	0.1	2.1	341 (+48)	33 (+6)	160 (+23)	4.0 (+1.1)
T_{12}: 75% of Rec. NPK + Zn + FYM	6.8	0.1	2.1	349 (+56)	34 (+7)	172 (+35)	6.6 (+3.7)
T_{13}: 75% of Rec. NPK + Zn + PSB + FYM	6.8	0.1	2.1	355 (+62)	34 (+7)	177 (+40)	7.0 (+4.1)
CD (P = 0.05)	NS	NS	0.3	18.3	2.8	14.4	1.76

:Figures in parenthesis indicate net gain or loss in initial available nutrient levels after experimentation

with chemical fertilizers improved organic carbon and available nutrient status of the soil than the treatment without FYM. Maximum available nitrogen (372 kg ha^{-1}), available potassium (183 kg ha^{-1}) and DTPA-extractable zinc (7.5 kg ha^{-1}) were observed with the application of Rec. NPK + Zn + PSB + FYM (T_7). FYM and Zn as $ZnSO_4$ were statistically at par in improving the zinc status of experimental soil. Increase in organic carbon content of the soil could be due to addition of organic matter through FYM followed by its slower decomposition rate on account of lower temperatures during winter season in the valley. It is very likely that when FYM is applied along with chemical fertilizers, it not only slowly releases nutrients, but also prevents the losses of nutrients from chemical fertilizers through denitrification, volatilization and leaching (Subba Rao, 2009). Beneficial effects of integrated use of organics, biofertilizers and chemical fertilizers on soil properties have been reported by many researchers (Acharya *et al.*, 1988; Singh and Brar, 1994; Bhat and Singh, 2005; Verma and Mathur, 2009).

It may be concluded that to sustain higher wheat yields and soil health under temperate Himalayas, recommended dose of NPK (T_2) should be supplemented with FYM (T_5), Zn + FYM (T_6) or Zn + PSB + FYM (T_7).

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Indian Journal of Ecology

Soil Arthropod Extraction Tullgren Funnel Method

Romila Akoijam, Badal Bhattacharyya and D.J. Nath

Department of Entomology, College of Agriculture, Assam Agricultural University, Jorhat 785013, Assam, India
E-mail: romi.ak9@gmail.com

Abstract: Laboratory experiments were conducted in the white grub laboratory, Department of Entomology, Assam Agricultural University, Jorhat, Assam to extract the soil arthropod from matured earthen and concrete floor composts. The soil arthropod were extracted by using Tullgren funnel with 40 watt electric bulbs at high light intensity and operated upto 72 hours. The population of soil arthropod extracted from earthen floor compost (40086.90/sq.m) was found to be higher as compared to compost with concrete floor (24603.60/sq.m). In both the composts, the highest population of extraction of soil arthropod (9574.80 and 6484.20/sq.m from earthen and concrete floor composts respectively) was recorded in the month of October and the lowest population of soil arthropod (3272.40 and 2030.10/sq.m from earthen and concrete floor composts respectively) was recorded during January. The population of soil arthropod from earthen floor compost showed positively significant correlation with compost temperature and moisture. Similarly, the population of soil arthropod from concrete floor compost showed positively significant correlation with compost temperature but with that of compost moisture exhibited positive but non-significant relationship. Various soil arthropod like collembolans, soil mites, pseudoscorpions, ants, larvae, earwigs and many unidentified species were recorded from both the composts. In both the composts, the maximum populations of collembolans (5423.70 and 2969.40/sq.m for earthen and concrete floor composts respectively) and soil mites (3211.80 and 2060.40/sq.m for earthen and concrete floor composts respectively) were recorded in the month of October and the lowest populations were found during January. The populations of collembolans and soil mites observed during January were found to be 1575.60 and 757.50/sq.m respectively for earthen floor compost and that of concrete floor compost were found to be 999.90 and 515.10/sq.m respectively.

Key Words: Soil arthropod, Tullgren funnel, light intensity, composts, extraction, population

The soil arthropod execute vital ecological functions in the environment. They are thought to be involved in processing of organic matter, stimulate activities of microbes and augmenting processes involved in soil structure, thereby promote the formation of humus in the soil. As the food passes through their guts, they break up organic matter into small fragments and thereby increase the total surface area for subsequent microbial establishment and decomposition. They are relatively sedentary and reflect the conditions of the soil habitat more than mobile macroarthropod. They respond to many different environmental variables and disturbances, and thereby they can indicate environmental stress through changes in species or community structure and finally can be explored as important indicators of the environment (Kay *et al.*, 1999). The soil micro-arthropod are small invertebrates, having a body size of 0.20 mm-10.24 mm. They belong to the phylum Arthropoda. The Tullgren funnel is a commonly used device to extract small invertebrate animals from soil samples (Tullgren, 1918). The sample is placed in a container with a base made from gauze with a mesh designed to hold soil particles but permit the organisms to pass. The container is arranged over a funnel, with a source of light above (Michael, 2009). The soil condition of Assam is generally acidic. Moreover, the state is also subjected to frequent floods and extensive water logging, it depletes the upper top fertile soil and it reduces and even stops the activity and survival of useful soil organisms, although fungi, molds, anaerobic bacteria and many soil arthropods have a broader tolerance and tends to multiply at lower pH values (Patil, 2010). However, there is great variation of soil characters as well as their corresponding arthropods population, according to different locations. In addition, the information on soil arthropods of Assam (especially meso and microarthropods) is very scanty and practically, no research work has been conducted systematically on this particular aspect. To know the quantitative distribution of different soil arthropods in different locations, extraction with Tullgren funnel method has been a new area of research. By estimating quantitative distribution of soil arthropods in different regions, the variation of their abundance, their role as bioindicators and their relationship with the existing environment can be understood. Therefore, this research work is proposed to be conducted with the objective to study the population of soil arthropods in matured composts.

MATERIALS AND METHODS

Collection of samples

Samples have been collected from six different places of the compost pit, which were developed by the Biofertilizer Section, Department of Soil Science, Assam Agricultural University, Jorhat. Two types of composts i.e. earthen floor compost and concrete floor compost were taken at fortnightly interval. The compost temperature was also recorded fortnightly with the help of soil thermometer. The moisture

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content was also determined by Gravimetric method (Kishore, Sharma and Pramanick, 2008). The samples were collected up to a depth of 10 cm, from the matured compost pit with the help of rectangular sampler having a size of 30 X 11 X 8 cm. These were filled in polythene bags and tied with rubber band. In the laboratory, samples were analyzed in the Tullgren funnel by adjusting high light intensity with 40 watt electric light bulbs and extraction process continued for 72 hours.

Collection and counting of soil arthropod

After completion of 72 hours, the extracted soil arthropod were collected in 70 per cent ethyl alcohol, which were then transferred to the Petridish. The extracted soil arthropod were counted and sorted out by using fine camel hairbrush.

Estimation of population of extracted soil arthropod

The composts samples collected by using rectangular soil sampler having size of the sampler, B × L (Breadth × Length in cm) and X number of soil arthropod were collected in the same sample at a constant depth of 10 cm, then according to Singh *et al.* (1978), the populations of extracted soil arthropod per square metre were estimated by using the formula,

$$P = \frac{10{,}000 \times X}{(B \times L)\, n}$$

Where, P = Population of soil arthropod per square metre
X = Number of soil arthropod extracted from the funnel
B = Breadth of the rectangular soil sampler (cm)
L = Length of the rectangular soil sampler (cm)
n = Number of samples per ecosystem

RESULTS AND DISCUSSION

The population of soil arthropod per square metre extracted from earthen floor compost was higher (40086.90) when compared with that of concrete floor compost. It may be due to the fact that in earthen floor compost, the soil arthropod prevalent in the deeper layers of soil or the nearby areas could migrate to the composting area as the floor of the compost was made up of earth which permitted their easy movement. Moreover, they always preferred soil or litter containing high organic matter and compost was originally high in organic matter content and other nutrients as compared to normal soils. Whereas in concrete floor compost, the floor of compost was made of cement concrete which may hinder the free movement of soil arthropod even if they present in the deeper layers or the nearby adjacent soil profiles. It can be mentioned that the level of phytotoxic chemicals and hazardous volatile organic compounds might be produced higher in concrete floor compost than that of earthen floor compost because of low rate of leaching. As most of the soil arthropod are soft-bodied invertebrates and hence, they are very sensitive to any toxic compounds and it was expected that due to these factors the population of soil arthropod in concrete floor compost was found to be less when compared with the population of soil arthropod in earthen floor compost. The present finding is in conformity with Young and Chou (2003), according to whom, many phytotoxic chemicals were produced during composting that might significantly impact on germination, plant growth, plant pathogens, *etc.* The major phytotoxic compounds include either phenolic compounds or short chain fatty acids. Some of the phenolics are vanillic, trans-p-coumaric, cis-p-coumaric, p-hydroxybenzoic, ferulic, and o-hydroxyphenylacetic acids; short chain fatty acids include acetic acid, propionic acid, and butyric acid. Similar findings were also observed by Komilis *et al.* (2004) and noticed that immature composting can be a source of hazardous volatile organic compounds.

The total Nitrogen, Phosphorus and Potassium for earthen floor compost were observed to be 0.75, 0.30 and 0.20 per cent respectively but that of concrete floor compost were found to be 0.99, 0.23 and 0.75 per cent respectively (Table 1). It showed that the nutrient composition of compost produced on earthen floor was found to be slightly lower than that of compost from concrete floor. It may be due to the fact that the higher populations of soil arthropod found in the earthen floor compost could facilitate the loss of nutrients through leaching as they might have created more pores in the compost floor as compared to that of concrete floor compost.

In both the composts, the highest population of extraction of soil arthropod was recorded in the month of October (Fig 1). A total of 9574.80 and 6484.20 per square metre of soil arthropod were extracted from earthen and concrete floor composts respectively October. It may be due to the fact that the compost temperature (27.50-28.50ºC) for earthen floor compost and 26-27ºC for concrete floor compost and moisture (28.60-29.72 per cent for earthen floor compost and 26.74-28.54 per cent for concrete floor compost during October) were more congenial for the growth of the soil arthropod. The lowest population of soil arthropod population was recorded during January and it was 3272.40 and 2030.10 per square metre of soil arthropod from earthen and concrete floor composts respectively. During January, the compost temperature and moisture were observed to be 17-17.50ºC and 20.54-21.24 per cent for earthen floor compost respectively and that of

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Table 1. Population of soil arthropod extracted by Tunnel funnel method (TFM) from both earthen and concrete floor composts during the period of August to January

Compost floor	Population of soil arthropod/ sq. m						Total number (%population)	Total N (%)	Total P (%)	Total K (%)
	Soil mites	Collembolans	Other arthropod populations							
			Pseudoscorpion	Ants	Larvae	Earwigs	Unidentified			
Earthen floor	11665.50	22240.20	1454.40	1181.70	818.10	818.10	1908.90	40086.90	0.75	0.30	0.23
Concrete floor	6878.10	10605.00	1302.90	909.00	909.00	575.70	3423.90	24603.60	0.99	0.20	0.75
Total	18543.60	32845.20	2757.30	2090.70	1727.10	1393.80	5332.80	64690.50			

(Figures in parentheses are the per cent values, N-Nitrogen, P-Phosphorus and K-Potassium)

concrete floor compost were observed to be 17.00-17.50°C and 20.47-20.98 per cent respectively. It shows that as the compost temperature and moisture decrease the populations of soil arthropod were also declined. During the course of investigation, the populations of soil arthropod were increased from August to October up to a certain level and the populations were declined from November to January (Fig 1).

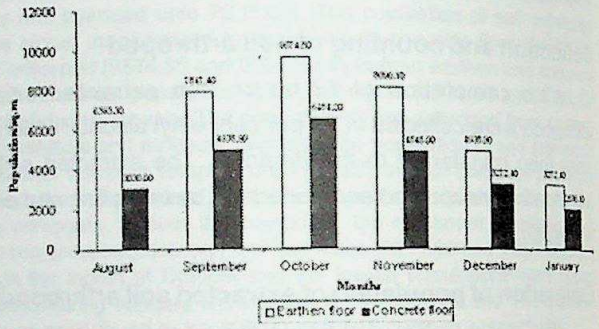


Fig 1. Population of soil arthropod/ sq.m extracted by TFM from matured composts (both earthen and concrete floors)

Various soil arthropod like collembolans, soil mites, pseudoscorpions, ants, larvae, earwigs and many unidentified species were recorded from both the composts. It indicated that they also play an important role to facilitate the decomposition of the composts. Furthermore, they are the soil arthropod which break down the organic matter into smaller pieces to hasten the decomposition process, nutrient cycling, feed on soil fungi, bacteria, *etc.* which are exceedingly prevalent in the compost. Among all the soil arthropod extracted, collembolans and soil mites were recorded in large proportion from both the composts (Fig 2). A total of 22240.20 and 10605.00 per square metre of collembolans were recorded from earthen and concrete floor composts respectively whereas a total of 11665.50 and 6878.10 per square metre of soil mites were observed from earthen and concrete floor composts respectively (Table 1). It can be mentioned that collembolans and soil mites have higher temperature and moisture preferandum compared to other soil arthropod. The population of collembolans was found to be higher than that of soil mites in earthen compost. It was apparent that the production of phytotoxic chemicals and hazardous volatile organic compounds might have more in concrete floor compost than that of earthen floor compost and collembolans could tolerate those phytotoxic chemicals that might produce more in the concrete floor compost than the soil mites. The population of collembolans and soil mites in both the composts were found to be maximum in October and the minimum during January. The populations of soil arthropod were slightly increased from the August to October but it

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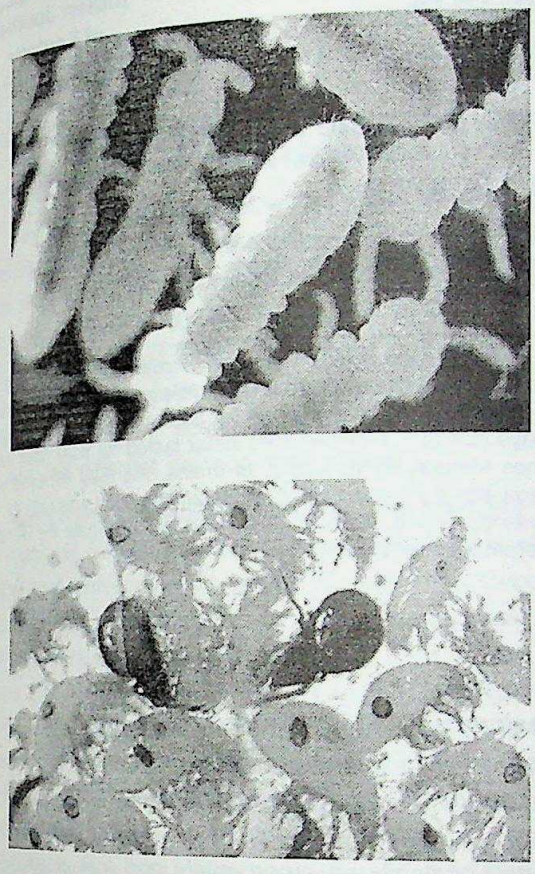


Fig 2. Soil arthropods extracted by TFM from composts

was again declined gradually from the November to January. It may be due to the fact that the decrease in the compost temperature and moisture affected the population of collembolans and soil mites. that the collembolans were the dominant groups which constituted 56 and 43 per cent in earthen floor compost and concrete floor respectively followed by soil mites in which 29 and 28 per cent in earthen floor and concrete floor composts respectively. The presence of collembolans and soil mites is considerably higher in numbers than the other soil arthropod in the matured compost indicates their possible key role in the decomposition process of the composts. During the course of study, nine morphologically dissimilar types of collembolans and eleven morphologically dissimilar types of soil mites were recorded.

Correlation studies indicate that the population of soil arthropod from earthen floor compost showed positively significant correlation (at P = 0.05) with compost temperature (r = 0.754) and moisture (r = 0.747) (Table 3). Likewise, the population of soil arthropod extracted from the compost with concrete floor showed positively significant correlation (at P = 0.05) with compost temperature (r = 0.448). However, a positive correlation

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Table 2. Correlation study of soil arthropod populations extracted by TFM both from earthen and concrete floor composts with compost temperature and moisture during August to January

Compost parameters	Correlation coefficients (r)	
	Earthen floor	Concrete floor
Compost temperature	0.754*	0.448*
Compost moisture	0.747*	0.496^{NS}

* Significant at 5 per cent probability level
NS=Non-significant

between the soil arthropod population from compost with concrete floor and compost moisture (r = 0.496) was observed but the relationship was found to be non-significant.

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Biology of *Phenacoccus solenopsis* Tinsley on *Bt* cotton

Sanjeev Kumar and J.S. Kular

Department of Entomology,
Punjab Agricultural University, Ludhiana-141004, Punjab, India,
E-mail: sanjeev4111982@rediff.com

Abstract: Biology of mealy bug, *Phenacoccus solenopsis* Tinsley studied on cotton hybrid RCH 134 under screen house conditions for two seasons. The pest was ovo-viviparous with three nymphal instars preceding adult stage. The total life cycle was completed in 33.40 days (range=27-40). The incubation period for both sexes varied from 1-2 days. The first instar lasted for 5.20 and 4.60 days (range = 4-6) in female and male, respectively. In female, second instar was 5.40 days (range = 4-7) and third instar lasted for 6.30 days. Adult longevity was 15.30. The females laid 3-4 ovisacs with 359.20 young ones through its life–cycle. In males, the total life cycle was completed in 19.50 days (range 15-23). The duration of 2nd and cocoon stage was 4.70 and 6.90 days. Adult longevity was only for 1-2 days. This study is very useful in the identification of various stages of *P. solenopsis* and can be further used to investigate the life table of this pest at different constant temperature to know its distribution in different regions of Punjab.

Key Words: *Phenacoccus solenopsis*, biology, *Bt* cotton

Cotton (*Gossypium* spp.) is a premier cash crop of India. Apart from its value as a fibre, it has great potential to use as edible oil. Among 111 cotton growing countries of the world, India is only country where four species of cotton viz. *Gossypium arboreum* L., *G.herbaceum* L., *G.hirsutum* L. and *G. barbadense* L. along with intra and inter specific hybrids, are grown (CAB, 2009). Among the cotton growing states of India, Punjab has prominent position with respect to production. The insect pest complex has changed considerably after the introduction of *Bt* cotton, in the last few years,. *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) has been emerged as one of the major pest of cotton, vegetables and fruits. In India *P. solenopsis* alone caused huge losses (7779.43 US$/ha), reduced average seed cotton yield (0.135 kg in infested plant as compared to 0.242 kg in healthy plant) (Dhawan *et.al.*, 2007) and 14 per cent losses to cotton cop during 2005 in Pakistan (PWQCP, 2005)

P. solenopsis is cottony in appearance, small, oval and soft bodied sucking insect, which is provided with short to medium sized waxy body filaments, anal filaments of one fourth body length and the two dark stripes on either side of the middle "ridge" of the body. It produces an egg mass in ovisac on aerial parts of the plants. This species is a polyphagous pest, which has found previously on relatively wide variety of host plants including species of economically important families such as cucurbitaceae, fabaceae, solanaceae in different parts of the world. It has also been reported on various weeds like *Parthenium hysterophorus* L. (*Congress grass*), *Trianthema monogyna* L. (*Shanti or itsit*), *Xanthium strumarium* L. (gutputna), *Achyranthus aspera* Linn. (puthkanda), ornamental plant i.e. *Hibiscus rosasinensis* Linn. (China rose) alongwith okra (*Abelmoschus esculentus*), tomato (*Solanum lycopersicum*), brinjal (*Solanum melongena*), chilli (*Capsicum annum*) (Tanwar *et al.*, 2008). *P. solenopsis* reported originally on ornamentals and fruit crops in the Mexico (Tinsley 1898) and regarded as an introduced exotic pest in India and Pakistan. During 2006, in Indian Punjab, mealy bug, *P. solenopsis* was first recorded on cotton crop in some pockets of Ferozepur (Abohar), Muktsar (Malout) and Bathinda (Sangat) districts. Subsequently, mealy bug also spread in area of Ferozepur, Bathinda and Muktsar districts of Indian, Punjab during 2007. *P. solenopsis* has attained the economic importance, in the Asian continent, so several studies on the biology of *P. solenopsis* have been done in diverse environmental conditions (Aheer *et al.*, 2009 Akintola and Ande, 2008, Patel *et al*, 2010, Kedar *et al* , 2010, Vennila *et al*, 2010, Kamariya and Patel, 2011 and Yi-Yong *et al.*, 2011). Due to polyphagous nature of *P. solenopsis*, various worker conducted their biological study on different hosts (David *et al* 2009, Abbas *et al* 2010 and Sana- ullah *et al.* 2011).

Such a vast distribution of *P. solenopsis* during last few year make it necessary to know the different stages of *P. solenopsis* on cotton, as it is main fibre of crop in Punjab. Keeping in view the above facts the present study was conducted to know various biological parameters of mealy bug like duration of different instars, number of ovisac/ female, fecundity / female and adult longevity on cotton. The ultimate goals of this study was to provide an understanding life cycle/ biological parameter of *P. solenopsis* to verify important life stages and provide basic information to farmers about the different life stages of *P. solenopsis* for

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the better management of this pest under Punjab state conditions.

MATERIALS AND METHODS

Seeds of cotton-hybrid RCH-134 were procured from Rasi Seeds Pvt. Ltd., Madhya pradesh and sown in earthen pots at Entomological Research Farm, Department of Entomology, PAU, Ludhiana. Earthen pots filled up with mixture of the soil and FYM (1:1) soil up to 2 cm from the upper edge. Thirty days old plants were used for conducting various experiments in screen house to know the life cycle duration and different development stages.

Nymphs and adults of *P. solenopsis* were collected from the cotton (*G. hirsutum*) and from perennial plants such as China rose (*Hibiscus rosa-sinensis),* cucurbits (*Cucumis* sp) and *Citrus* sp. Different immature stages were also collected from non- host like peeli buti (*Sida acuta*), gut putna (*Xanthium strumariun*), kangi buti (*Abutilon theothrasti*) and datura (*Datura stramonium)* were also collected. These immature and adult stages collected from cotton belt of Punjab state including Bathinda, Muktsar and Faridkot, fields, adjoining to the university in Ludhiana district. Population were reared in earthen pots of 26 cm in diameter, during *kharif* and winter. After one generation, on different hosts, *P. solenopsis* transferred to cotton plant for conditioning and adaptations to maintain uniformity of mealy bug population. First instar nymph *P. solenopsis* collected from the colonies reared on cotton and used in the experiment to record different stages of this pest. During winter, the colonies maintained on different host plants and temperature maintained by using electrical heater under screen house conditions. Similarly, colonies also reared on cuttings of tender parts of *Hibiscus rosa-sinesis*, *Citrus* spp., tomato (*Solanum lycopersicum)*, brinjal (*Solanum melongena*) and congress grass (*P. hysterophorus).* These cuttings were replaced by new ones after every three days, with the help of camel hairbrush carefully. In the laboratory the temperature of 30±1°C was maintained with the help of REMI incubator (Remi House, 3rd Floor, 11, Cama Industrial Estate Walbhat Road, Goregaon (East) Mumbai - 400 063, India) so that favorable conditions were provided for multiplication of mealy bug on their hosts. The study conducted between August and October 2008 and 2009 in screen house when maximum and minimum temperature and mean relative humidity of the study area ranged from 27.3 to 37.5° C and 18.3 to 29.4° C, and 51.5 to 83.1 per cent relative humidity, respectively. A single newly emerged adults/ female taken from the culture and were transferred to cotton plant. There were 15 plants of cotton, which used, and each plant assumed as one replication. The observations on incubation period, nymphal duration, adult longevity, number of ovisacs / female, Number of eggs / ovisac and per cent survival were recorded. Incubation period worked out by detaching the ovisac immediately from gravid *P. solenopsis* female and then number of nymphs emerged per ovisac were observed untill the every single crawler released from ovisac. The duration of different nymphal stages and longevity of adult worked out in days and each instar separated with the presence of exuviae. These observations recorded with the help of lens, as the eggs and crawler of *P. solenopsis* were very small. Total life cycle duration also worked out by adding duration of all the immature stages. To calculate the percent survival, thirty plants taken on which single first instar nymph released individually. From these the percent survival recorded after each molt when the mealy bug shifted to next instar.

Total No. of crawler released/ ovisac

The data collected for various observations subjected to analysis of mean and standard deviation with the help of CPCS1 programme and range was calculated simply by using the Microsoft excel functions. The percent survival calculated by using following formula: -

$$\text{Survival (\%)} = \frac{\text{Number of immature passed to next stage}}{\text{Total No. of crawler released/ ovisac}} \times 100$$

RESULTS AND DISCUSSION

The eggs hatched within one to two days. The mean period for incubation was 1.50 ± 0.50 (1-2 days) in case of female while 1.40 ± 0.50 in male. The eggs stage of both sexes was indistinguishable from each other. There was no distinction in first instar of male and female. Both the sexes (male and female) completed their first instar in 5.20 ± 0.84 days (female) (Table.1) and 4.60 ± 0.82 days (male). The range varied from 4 to 6 days in both the male and female. Second instar lasted for 5.40 ± 1.00 (4-7 days) in female and the male completed this stage within 4.70 ± 0.82 (4-5 days). Females were distinguished from males by white waxy covering on the entire body at third instar, so, in case of male this was consider as pre-pupal and cocoon stage as it was difficult to distinguish between these two stages. The duration of this instar ranged between 5-7 days (6.30 ± 0.90) in females and 6-8 days (6.90 ± 0.50), in males, respectively. The adult period/adult longevity of female was 15.60 ± 1.62 days with range of 13 to 18 days. On the other side, the adult male lived for only 1-2 days (1.70 ± 0.49), as these was no mouthparts to feed (Table 2). The both sexes also marked easily as the female is fully covered with white waxy and 2 black stripes on the dorsal side of body/ abdomen, while male has one pair of wings and small in

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Table 1. Duration of different developmental stages of female mealy bug, P. solenopsis Tinsley on cotton

Particular	Duration of different development stage of P. solenopsis								
	Egg* (Incubation period)	Nymph			Adult		Total	Number of ovisacs per female	Number of young ones released per female	Adult longevity (Days)
		First	Second	Third	Pre-oviposition	oviposition	Post-oviposition			
(Mean ± SD)	1.5±0.5	5.0±0.6	5.4±1.0	6.3±0.9	4.5±0.6	7.2±1.1	3.4±0.7	33.4±2.4	3.7±0.5	359.2±24.4	15.3±1.70
Range	1-2	4-6	4-7	5-7	4-5	6-9	3-4	27-40	3-4	280-380	13-18
Survival (%)	-	81.67	89.75	100.00		100.00		-	-	-	-

size than female. The ovipositional behavior of adult female was also studied and there were three different stages i.e. Pre- ovipositional, ovi-positional and post ovi-positional stage. The pre-ovipositional period was normally varied from 4 to 5 (4.5 ± 0.60) days. Female has 6-9 (7.20 ± 1.10) days ovi-positional period in which the adult female laid eggs which were packed in an ovisac. After the egg laying/ovisac, the female live for 3 to 4 (3.4 ± 0.54) days which as post-ovipositional period. Female fecundity varied from 289 to 380 (359.20 ± 24.40) young ones/female and each adult female laid 3 to 4 (3.60 ± 0.49) ovisac throughout its life period (Table. 2).Life- cycle/ Total number of days to complete one generation by adult female and male in 27 to 40 (33.40 ± 2.40) days and 15-23 (19.20 ±1.33) days, respectively. The survival of *P.solenopsis* was studied in case of female and only first, 2nd 3rd and adult stage was selected for the per cent survival. There was only 19.33 per cent mortality with first instar therefore 81.67 percent survival), 91.07 Per cent in 2nd instar and 100.00 per cent survival for both 3rd and adult stage. This study shows that first and 2nd instar was more prone to death rather than 3rd instar and adult stage.

The available literature on the biology of this mealy bug species is quite less, as it attained the status of major pest of cotton is recent years. Most of the scientists worked out the biology of *P. solenopsis* under controlled conditions where as this study done on the potted plant under screen house. This study conducted by Dhawan and saini in 2009, revealed that the total life cycle completed in 27-38 in female and 16-23 in male, where as it was 27-40 days and 15-23 days in female and male, respectively. Similarly, Kedar *et. al* (2010), recorded the biology parameter of *P. solenopsis,* in which female took 31-36 days and male 17-22 days to complete their life cycle. The total life cycle of a closely related species *P. madeireusis* was 30, 46 and 66 days, at constant temperature of 25, 20 and 15ºC, respectively (Chong *et al,* 2003).

This study is in accordance with Dhawan and Saini (2009) in which they recorded incubation period for 1-2 days. Whereas, the other scientists recorded this period in hours in which it took only 3.00 minute (Kedar *et al* 2010), 30-45 minutes (Aheer *et al.*, 2009), 35-60 minutes (Patel *et al.*, 2010) and 35-120 minutes (Venilla *et al.*, 2010). Among the nymphal instars, female had three instars while male had two instars and the longest cocoon stage. Duration of nymphal instars was 5.00, 5.40 and 6.30 days (for first, second and third instar respectively) in female, however it was 4.60, 4.70 and 6.90 days in first, second and cocoon stage of male. Antikola and Ande (2008) recorded that female had 6, 8 and 10 days for first, second and third

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Table 2. Duration of different developmental stages of male mealy bug, Phenacoccus solenopsis Tinsley on cotton

Particulars	Duration of different development stage of P. solenopsis						
	Egg (Incubation period)	Nymph		Pre pupal & cocoon stage	Adult	Total	Adult longevity (Days)
		First	Second				
(Mean ± SD)	1.40±0.50	4.60±0.82	4.70±0.62	6.90±0.50	1.70±0.49	19.50±1.49	1.70±0.49
Range	1-2	4-6	4-5	6-8	1-2	15-23	1-2

instar, respectively. Venilla *et al* and Patel *et al* (2010) reported that male has four instars, while this study concluded that male of *P. solenopsis* had 2 nymphal instars along a cocoon stage, which are in accordance with the studies carried out by Dhawan and Saini, 2009; Aheer *et al.*, 2009; Kedar *et al.*, 2010.

In this study, the full-grown second instar nymphal secreted white cocoon around its body and pupated in side as observed in the study conducted by Aheer *et al* 2009. The total adult longevity of female *P.solenopsis* was 15.3 days, while 1-2 days in male. The adult longevity of female and male *P. solenopsis* observed in different studies was 14.8 and 1.6 days; 19 and 1.9 days, receptively (Dhawan and saini, 2009; Kedar *et al.* 2010), while 7-10 and 32-35 days, respectively in the study conducted by Patel *et al.* (2010).

The female adult had three distinct phases viz., pre-oviposition, oviposition and post- oviposition. The duration for 3 phases was 4.5, 7.2 and 3.4 day (in this study), while 5-96, 10.08 and 3.00 days (in Kedar *et al.*, 2010). Similarly, study conducted by Patel *et al.*, 2010 observed that these phases were 2 times more than the present study under screen house as they recoded there phase as 8.56, 16.73 and 9.33 days. In present study, *P. solenopsis* female produced young one ranged 280-380, when reared on cotton with 3-4 ovisacs/female on cotton at Haryana state of India. The another species of mealy bug (*Maconellicocuues hirsutus*) produced 260-300 eggs on hibiscus cutting at 20-27°C 178 eggs with 8 days on hibiscus plants at 27° c, and 162 eggs on Japanese pumpkin , respectively (Chong *et. al.*, 2008; Persad and Khan, 2002 and serrano and Lapointe, 2002). The difference in fecundity of *P. solenopsis* as well as *M. hirsutus* in these studies likely the result of variability of host plant species and controlled conditions. This information may also be helpful in studying the biological parameters on different constant temperatures and relative humidity. Which explore the possibility of vulnerable temperature and or their combinations to manage the susceptible stages of *P. solenopsis* on cotton or other related plants of economic importance.

This study provides information about the identity of various instars, which help the farmer to identity the various stages at field level. Based on the identification farmer excuse that at which stage the IPM tactics should applied to kept population below ETL. This study also suggested that due to shorter life cycle of female and more ability to produce/ fecundity can cause its spread in the Asian-continent as it as already established and caused damaged in Pakistan and India. *P. solenopsis* males played minor role in reproduction, so under field condition the management of female should be ensure to manage the population of *P. solenopsis* This study provides an information that the nymphal stages/ crawler lack the waxy coating and remained for 14-20 days in held. To make a decision for this management with insecticides regular surveillance of the field needed, so that the nymphal stages can control to reduce the population *P. solenopsis.* This study may also be helpful in ecological modeling by determine survival and development of *P. solenopsis* at different temperatures on various host plants. There is also a need of molecular studies on the variations in their population and other species of mealy bug as the report provided by Hodgson *et al*, 2008 suggested that these species of *Phenacoccus* genra are same and little variation due to the environmental factors.

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Indian Journal of Ecology

Habitat Alteration to Manage Pests and Augment Natural Enemies in Rainfed Pigeonpea

G. Anitha

All India Co-ordinated Research Project on Biological Control, ARI Campus, Rajendranagar, Hyderabad – 500 030
E-mail: anitha.gorthi@yahoo.com

Pigeonpea is an important pulse crop of rainfed areas in our country. Infestation by pod borers, mainly *Helicoverpa armigera* is a major constraint in achieving good yields. Conventional control measures include the use of chemical insecticides for its management. Increasing insecticide resistance has lead to greater risk of control failure (Armes *et al.*, 1992). Research in diversified agro-ecosystems demonstrated that these systems tend to support less herbivore load than the corresponding monocultures (Risch,1981 and Altieri and Letourneau,1982). Hence, an experiment was laid out to study the influence of crop habitat diversity on the pest intensity and biodiversity of natural enemies in pigeonpea.

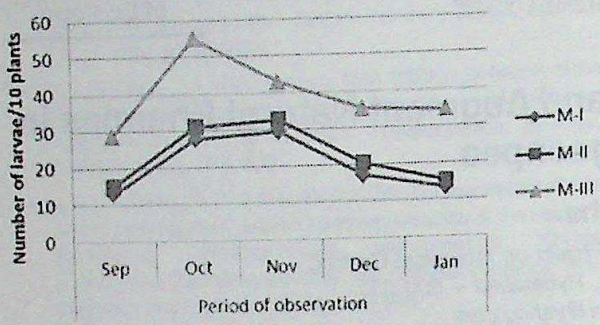
The field study was conducted in the research farms of Rajendranagar in *kharif* seasons of 2009-10 and 2010-11 on variety Asha (ICPL 87119) of pigeonpea. Habitat diversity was created using border crops and intercrop. The experiment was laid out in three blocks: a) M-I had pigeonpea:sunflower in 9:1 ratio and sorghum as the border crop (two rows all around the block), b) M-II had pigeonpea:sunflower in 9:1 ratio and maize as the border crop (two rows all around the block), c) M-III had pigeonpea as the solecrop. The size of each block was 500 sq.m. Local hybrids of sunflower, sorghum and maize were sown such that their flowering time synchronized with that of pigeonpea. Agronomic practices followed for all the blocks were similar. Pest and natural enemy counts were taken from 25 randomly tagged plants per block once every fifteen days starting from 30 days after sowing. Population of the pests and natural enemies was pooled month-wise, transformed and analysed using ANOVA.

Population of *H. armigera* built up from 35 Std. WK (September), attained a peak in 44 Std. WK (November) and decreased gradually by January. Leafhoppers infested the crop from 31 Std. Wk but the maximum population was recorded in 51 Std. Wk. Aphids were observed only in December and January. Analysis of two years' pooled data revealed that module with sorghum as the bordercrop registered significantly lesser population of *H. armigera* (13-29.4/10 plants), leafhoppers (19.3-48.2/10 plants) and aphids (113-170.4/10 plants). Module with maize registered lesser population (15.1-32.7/10 plants) of *H. armigera* and was on par with the sorghum module (Fig.1.). However, population of leafhoppers and aphids was higher (35.3-73.4 and 171.6-212.9/10 plants resp.) and on par with the sole crop (36.7- 75.0 and 180.1-220.1/10 plants resp.) (Fig.2 & 3). The main crop harboured lesser population of *H.armigera* as the population could have been distributed among the bordercrop and the intercrop as all of them flowered simultaneously. Maize as a bordercrop was found to be more successful in evading the pod borer than against aphids and leafhoppers. In experiments by Srinivasa Rao *et al.* (2006), sole crop of pigeonpea had higher infestation of 0.54 larvae of *H.armigera*/plant, while that intercropped with sorghum and castor recorded infestation of 0.40 and 0.43 larvae/plant resp. Incidence of *Helicoverpa* was low in pigeonpea intercropped with soybean and sorghum when compared with other combinations like cotton, greengram and groundnut (Venugopal Rao *et al.*, 1992).

Spider and Coccinellid activity was observed from 31 STD WK to 51 STD WK i.e from August to January. Observations recorded on their populations showed that both the modules with the altered crop habitats recorded significantly higher populations compared to the sole crop. Spiders ranged from 5.1-10.5 /10 plants in the intercropped modules while it was 1.1-6.3/10 plants in the monocropped module (Fig.4.). Coccinellids recorded in the intercropped modules were higher (5.9-19.1/10 plants) while their numbers in the sole crop were less (3.2-15.5/10 plants) (Fig.5.). The bordercrops specially sorghum was infested by shootbugs, which attracted natural enemies like mirids, Chrysopids, *Orius* spp., *Xylocoris falvipes* and carpenter ants. Creating habitat diversity ensures better activity of natural enemies by providing nectar, pollen, honeydew as food for their adult stages and offering "shelter" for them. Predators showed a clear preference for sorghum as

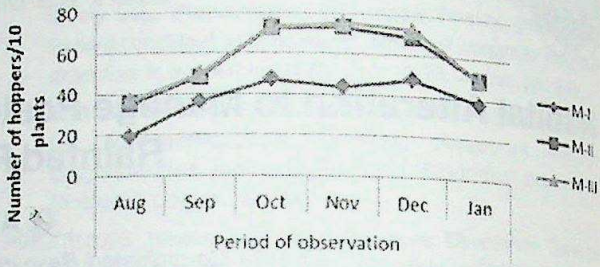
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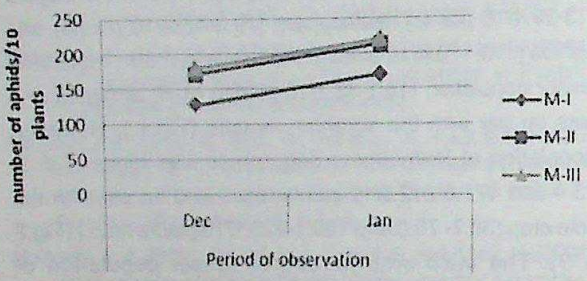
*Pooled data of 2009-10 and 2010-11

Fig.1. Impact of habitat alteration on H.armigera*



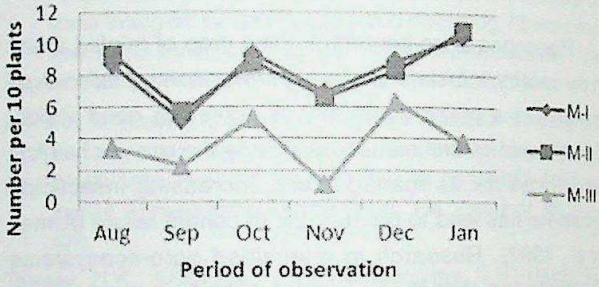
*Pooled data of 2009-10 and 2010-11

Fig.2. Impact of habitat alteration on leafhoppers*



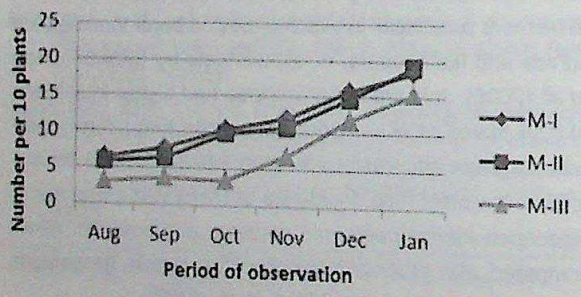
*Pooled data of 2009-10 and 2010-11

Fig. 3. Impact of habitat alteration on aphids*



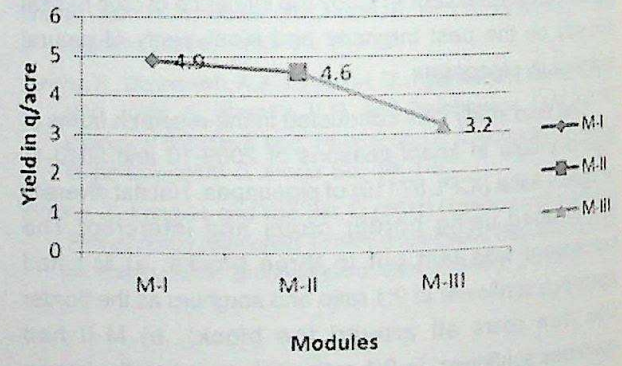
*Pooled data of 2009-10 and 2010-11

Fig. 4. Impact of habitat alteration on spiders*



*Pooled data of 2009-10 and 2010-11

Fig.5. Impact of habitat alteration on Coccinellids*



*Pooled data of 2009-10 and 2010-11

Fig.6. Impact of habitat alteration on yield of pigeonpea*

M-I had pigeonpea and sunflower in 9:1 ratio and two rows of sorghum all around the field as bordercrop
M-II had pigeonpea and sunflower in 9:1 ratio and two rows of maize all around the field as bordercrop
M-III had pigeonpea as the sole crop

intercrop where numbers peaked during flowering the stage of pigeonpea (Rao *et al.*, 2003).

The intercropped modules recorded significantly higher yields than the sole crop. Yield of pigeonpea in these modules ranged from 4.6-4.9 q/acre, while that in the sole crop was 3.2q/acre (Fig.6.). In an experiment conducted by Nderitu *et al.*, 2008, plots bordered by pigeonpea and maize had lowest and highest mean aphid population among four border crops pigeonpea, maize, sorghum and millet tested, respectively. However, maize bordered plots recorded the highest number of parasitized aphids in both seasons.

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Indian Journal of Ecology

Forage Varieties of Maize to Varying Levels of Nitrogen

Chhavi Sharma, C.S. Panwar and G.S. Rathi

Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur-482004 (M.P.), India
E- mail: chhavisharma3@gmail.com

Forage crops are one of the cheapest source of feeds to livestock as they not only meet the requirement of bulk to be fed to animals but also provide quality diet if fertilized and harvested at proper stage of growth. Among various forage crops grown to feed the animals, maize is an important forage crop of rainy season. It is quick growing which provides energy rich, nutritious and palatable fodder to livestock. As a fodder crop, it is used for green feeding, making hay and silage for scarcity period of the year. In recent years, many improved varieties of maize have been evolved which have high yield potential are being grown for producing green fodder as well as seed. Various agronomic management techniques have been developed to enhance the fodder yield of maize, among them the application of nitrogen has been found to be the most important as it plays key role in growth and development of plants. Present study was therefore, designed to find out the most suitable for "forage varieties of maize to varying levels of nitrogen for higher yield"

A field experiment was conducted during *Kharif* season of 2008-09 at Research Farm, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) which lies between 22° 49' to 24° 8' North latitude and 78° 21' to 80° 58' East longitude with an altitude of 411.78 meters above the mean sea level. The soil was black in colour, sandy clay loam in texture, neutral in reaction with normal electrical conductivity (0.40 dS m^{-1}). The OC content were (0.42%) in the soil and analyzing in low available N (227 kg ha^{-1}), P (16.2 kg ha^{-1}), and medium available K (275 kg ha^{-1}) contents. The experiment was laid out in factorial randomized block design with sixteen treatments consisted of four varieties (African tall, HQPM, JM-218 and JM-216) and four levels of nitrogen (20, 40, 60 and 80 kg ha^{-1}) with three replications. A uniform dose of 60 kg P_2O_5 and 20 kg K_2O per hectare was given to all plots along with N as per treatments. Sowing was done uniformly in all the plots by drilling the seed @ 40 kg/ha in rows 30 cm apart manually on July 13, 2008. Before sowing the seeds were treated with the mixture of Thirum (2g kg^{-1}) + Bavistin (1g kg^{-1}) of seeds.

Growth parameters, quality and yield

Variety African tall significantly recorded tallest plants, highest number of leaves per plant and maximum values of leaf area index at harvest among the varieties (HQPM, JM-218 and JM-216). Application of 80 kg N ha^{-1} significantly increased the plant height, number of leaves per plant and LAI than in other treatments (Table1). Leaf:stem ratio remained unaffected due to different varieties except African tall which was significantly superior than other varieties (HQPM, JM-218 and JM-216). Application of nitrogen showed its significant effect on leaf:stem ratio, and increased with increase in dose of nitrogen.

Variety JM-216 being at par to HQPM recorded maximum dry weight of leaves per plant followed by JM-218 and African tall, but variety HQPM increase in weight was more in stem than leaf (Table 2). Increasing level of nitrogen from 20 to 80 kg ha^{-1} recorded increase in dry weight of leaves and stem. Interactions between varieties and different rates of nitrogen, showed that application of 80 kg N ha^{-1}, JM-216 (dry weight of leaves per plant) with JM-218 (dry weight of stem per plant) ranked first and became significantly superior to others. Dry weight of stem per plant increase in African tall and HQPM was faster between 40 and 60 kg N ha^{-1} whereas varieties JM-216 and JM-218 recorded markable values between 60 and 80 kg N ha^{-1}. Variety African tall was superior in producing green fodder, dry matter as well as crude protein yields compared to other varieties (Table 2). The results are in conformity with the findings of Singh *et al.* (1995) and Banerjee and Singh (2003). These yields were increased from 310.21 to 368.93 q ha^{-1} for green fodder, 54.35 to 84.61 q ha^{-1} for dry matter and 3.86 to 7.07 q ha^{-1} for crude protein yields with increase in nitrogen from 20 to 80 kg ha^{-1}. The interaction between varieties and nitrogen levels for best combination of variety African tall @ 80 kg N ha^{-1} can be successfully utilized for maximum reap of fodder, dry matter as well as crude protein yields (Table 2).

Economic Analysis

Cost of cultivation varied due to application of the varying levels of nitrogen. The cost of cultivation was maximum (Rs 12473 ha^{-1}) with 80 kg N/ha under all the varieties. Among

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Table 1. Growth parameters of fodder maize varieties to varying levels of nitrogen

Treatments	Plant height (cm) At harvest	Leaves per plant (At harvest)	Leaf area index (50 DAS)	Leaf:Stem ratio
Varieties				
African tall (V_1)	205.81	17.38	14.86	0.62
HQPM (V_2)	160.34	15.32	12.05	0.58
JM-218 (V_3)	168.59	15.12	12.41	0.58
JM-216 (V_4)	166.78	15.22	14.05	0.58
Nitrogen levels (N) in Kg/ha				
20 (N_1)	158.89	14.80	9.54	0.49
40 (N_2)	171.21	15.53	12.44	0.56
60 (N_3)	181.23	15.67	14.68	0.63
80 (N_4)	190.19	16.70	16.71	0.68
CD (p=0.05)	0.52	0.21	0.21	0.02

Table 2. Dry weight, fodder yield, protein yield and production efficiency of fodder maize varieties to varying levels of nitrogen

Treatments	Dry weight of leaves per plant (g)	Dry weight of stem per plant (g)	Green fodder yield (q ha^{-1})	Dry matter yield (q ha^{-1})	Crude protein yield (q ha^{-1})	Production efficiency of varieties (q ha^{-1}/day)	
						Green fodder	Dry matter
Varieties (V)							
African tall (V_1)	24.66	38.76	418.79	77.76	6.68	5.58	1.03
HQPM (V_2)	25.51	43.07	310.27	63.81	5.07	4.70	0.96
JM-218 (V_3)	24.96	41.90	317.63	66.96	4.76	5.29	1.11
JM-216 (V_4)	25.68	42.18	325.75	67.67	5.20	5.42	1.12
Nitrogen levels (N) in Kg/ha							
20 (N_1)	14.45	29.33	310.21	54.35	3.86	4.74	0.82
40 (N_2)	19.64	35.09	335.55	64.71	4.85	5.13	0.99
60 (N_3)	28.30	44.79	357.74	72.52	5.93	5.47	1.11
80 (N_4)	38.42	56.71	368.93	84.61	7.07	5.64	1.29
CD (p=0.05)	0.59	0.69	7.04	1.99	0.16	-	-
Interaction (VXN)							
V_1N_1	13.26	26.69	383.7	65.08	5.27	5.11	0.86
V_1N_2	14.61	30.49	412.0	71.81	6.03	5.49	0.95
V_1N_3	32.26	46.70	431.5	77.58	6.82	5.75	1.03
V_1N_4	38.49	51.19	447.8	96.60	8.62	5.97	1.29
V_2N_1	13.82	27.06	285.9	54.09	3.82	4.33	0.81
V_2N_2	19.87	35.76	299.3	59.46	4.50	4.53	0.90
V_2N_3	31.09	51.41	323.6	67.09	5.54	4.90	1.01
V_2N_4	37.27	58.03	332.2	74.59	6.44	5.03	1.13
V_3N_1	14.98	31.02	387.7	50.72	3.12	4.79	0.84
V_3N_2	20.99	36.68	309.7	61.36	4.02	5.16	1.02
V_3N_3	25.30	40.71	332.1	73.05	5.55	5.53	1.21
V_3N_4	38.58	59.20	340.9	82.71	6.36	5.68	1.37
V_4N_1	15.76	32.54	283.4	47.53	3.24	4.72	0.79
V_4N_2	23.10	37.43	321.1	66.24	4.88	5.35	1.10
V_4N_3	24.54	40.36	343.7	72.36	5.81	5.72	1.20
V_4N_4	39.33	58.41	354.6	84.56	6.87	5.91	1.40
CD (p=0.05)	1.48	1.39	14.09	3.98	0.32		-

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the varieties, African tall recorded the maximum Gross monetary return (GMR) of Rs 25126 ha^{-1} it was followed by JM-216, JM-218 and HQPM which recorded the Gross monetary return (GMR). Every increasing level of nitrogen from 20 to 80 kg ha^{-1} significantly increased the green fodder yields. Therefore, the highest dose of nitrogen (80 kg ha^{-1}) gained the maximum GMR of Rs 22133 ha^{-1} which declined as Rs 21463, 20131 and 18610/ha with decrease in application of nitrogen as 60, 40 and 20 kg ha^{-1}, respectively. Variety African tall being top yielder fetched the maximum net profit of Rs 12983/ha, variety JM-216 was next to it (Rs 7399/ha) in this regard. The gain of profit by JM-218 and HQPM was Rs 6913 and 6472/ha respectively. The treatment with minimum dose of nitrogen fetched the minimum net profit of Rs 6797/ha which increased to Rs 9660/ha with application of 80 kg N/ha. Increase in green fodder yields due to corresponding increase in nitrogen levels registered increasing GMR and ultimately the net profit under these treatments. Similar findings were reported by Lakho *et. al.* (2004). The B:C ratio with variety African tall was maximum (2.07) among all the varieties tested in the experiment. The more profitability under this variety may be due to its higher yield potential as well as gross monetary returns and accordingly 1.61, 1.57 and 1.53 recorded with JM-216, JM-218 and HQPM, respectively. The profitability index was minimum (1.58) when 20 kg N/ha was applied, but every incremental dose of N as 40, 60 and 80 kg/ha markedly increased the profitability as 1.67, 1.75 and 1.78, respectively. It shows that application of higher doses of nitrogen was more remunerative due to increase in green fodder and gross monetary returns. These results corroborates with the finding of Ameta and Dhakar (2000).

The present studies show that African tall recorded significant superiority in producing more plant height, higher number of leaves, leaf:stem ratio, crude protein yield and recorded higher gross monetary returns, net monetary returns as well as benefit:cost ratio compared to other varieties. The nitrogen application significantly increased growth parameters plant height, number of leaves per plant and leaf area index. Therefore, green fodder, dry matter and crude protein yields under higher dose of nitrogen (80 kg/ha) were higher. Based on these findings, nitrogen (80 Kg ha^{-1}) and variety (African Tall) was the best combination for getting higher green fodder yield of maize under Jabalpur condition.

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Constraints in Adoption of Improved Dairy Farming Practices in Punjab

G.S. Aulakh, R. Aggarwal* and Karamjit Sharma[1]

Punjab Agricultural University
Krishi Vigyan Kendra, Faridkot
[1]Krishi Vigyan Kendra, Muktsar
**E-mail:renukaaggarwal@yahoo.com*

Abstract : The present study was conducted in six villages randomly selected from three districts of Punjab viz. Bathinda, Ferozpur and Sangrur during 2008-09. The data were collected from farmers through pre tested structured interview schedule. The study revealed that the majority of dairy farmers belonged to different categories of herd size faced the breeding and feeding constraints as serious. 87.78 percent and 68.33 percent of the dairy farmers perceived availability of poor quality semen and long calving interval in buffalo aspects of breeding as the major constraints. High cost of concentrate(86.11%), mineral mixture(71.48%) and lack of knowledge (68.70%) were the major constraints in adoption of improved feeding practices. The improvement in breeding practices can be achieved by providing good quality semen and elite bulls to the dairy farmers at their door steps. Moreover, price & the availability of concentrate feed should be under proper check. Mineral mixture should be provided to the farmers at low rate in sufficient quantity.

Key Words: Dairy farmers, Breeding constraints, Feeding constraints

In India, buffalo has been the backbone of rural economy as this animal form an integrate part of the farming system. It is the most domestic animal, not only provides milk but also used as a draft animal and is also considered more useful for reasons of higher fat content in milk and its ability to utilize agricultural byproducts more efficiently.

India is the largest milk producing country in the world with annual milk production of 121 million tonnes, but the per capita consumption of milk in India is 252 g whereas the world average is 300 g.The cattle & buffalo population is 178938(000) and 93225(000), respectively. So, India is at number one in milk production due to large live stock population and not due to production potential of dairy animals. Punjab is also one of the major milk producing state of the country i.e. 9385(000)tonnes and the per capita availability of milk is 915 g (Anonymous, 2010). The Murrah and Nili Ravi are the famous breeds of buffalo found in Punjab and are well known for milk production. Though the situation of per capita availability of milk in Punjab is better than rest of the country, still there is lot of scope for improvement in scientific dairy farming practices. The adoption of improved dairy practices, therefore, becomes a pre-requisite for sustained growth and development of dairy industry. But there are innumerable constraints before the farmers and consequently they are not adopting the recommended practices to the desired extent. Keeping this fact in view, the present study was undertaken to ascertain various constraints perceived by the dairy farmers in adoption of improved breeding and feeding practices.

The present study was conducted in three districts namely Bathinda, Ferozpur and Sangrur of Punjab during 2008-09. The sampling procedure employed to select ultimate unit of sample was multi stage sampling technique. One block was selected from each district then two villages were selected from each selected block. So, total six villages form the sample of the study. Three categories of dairy farmers were identified on the basis of number of adult buffalo possessed by them, namely small dairy farmers(1-2 adult buffalo), medium(3-5 adult buffalo) and large(more than 5 adult buffalo). A separate list of all buffalo owners was prepared for each selected village and thirty respondents were selected randomly by using proportional size of sampling technique. Thus, the total sample size for the study was 180 dairy farmers.

To find out the constraints perceived by the dairy farmers, a list of various constraints in the area of breeding and feeding were prepared in consultation with extension scientists, available literature, field veterinarians and progressive dairy farmers. The dairy farmers were asked about the extent of seriousness of these constraints on three points continuum i.e. very serious, serious and somewhat serious and the weight-age of 3,2 and 1 were given, respectively. The ranks were assigned on the basis of mean per cent constraint score. The respondents were categorized into three groups of seriousness namely very serious, serious and somewhat serious using mean and one standard deviation formulae.

The overall analysis of 180 respondents as indicated in Table 1 revealed that 57. 22, 22.78 and 20.20 per cent of the dairy farmers reported breedingese constraints as

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'serious', 'very serious' and 'some what serious', respectively. These findings get support from the findings of Ghosh and Chand (2001), Saha and Kumar (2003). However, the overall response of respondents regarding feeding constraints revealed that about one forth (i.e. 24.24%) of them reported these constraints as 'very serious'. whereas 65.00 and 10.56 per cent of them reported feeding constraints as 'serious' and 'some what serious', respectively. These results are in also line with the findings of Das and Malik (2003).

Table 1. Overall constraints perceived by dairy farmers in adoption of Improved breeding and feeding practices

Aspects	Category	Dairy farmers(n=180)	
		Frequency	%
Breeding	Somewhat serious	36	20.00
	Serious	103	57.22
	Very serious	41	22.78
Feeding	Somewhat serious	19	10.56
	Serious	117	65.00
	Very serious	44	24.44

Constraints in adoption of improved breeding practices

Eight important constraints were included related to breeding (Table 2).The 'poor quality of semen' (87.78%) was considered as the most serious constraint of breeding and hence ranked at first position. The second most serious constraint was 'long calving interval in buffalo'(68.33%). The last rank i.e. 8th was allotted to 'timely availability of A.I experts' meaning, thereby that 50 per cent of the dairy farmers perceived this constraint. The other serious constraints were 'long calving interval in buffalo', 'non availability of elite bulls', 'silent heat' and 'inbreeding in buffalo'. The perception of these constraints slightly varied in nature among all the three categories of respondents. Similar observations were also reported by Singh and Chauhan (2006) and Singh *et al* (2009).

Constraints in adoption of improved feeding practices

The data depicted in Table 3 revealed that majority of the respondents (86.11 %) felt that 'high cost of concentrate mixture' was the major constraint in adoption of improved feeding practices in buffalo rearing. The respondents assigned the second, third, fourth and fifth ranks to the constraints namely 'high cost of mineral mixture','lack of knowledge regarding improved feeding practices',' non-availability of seed of improved varieties of fodder'and 'non-availability of green fodder'. The intensity of these constraints in descending orders were 71.48, 68.70 , 67.78 and 59.44 per cent, respectively. Almost similar trend regarding perception of constraints were also found across all the different categories of respondents in adoption of feeding practices. These findings are in conformity with the findings reported by Dhaliwal and Singh (2003), Mohi and Bhatti (2006), Kumar *et al* (2009) and Rathore *et al*(2009).

It is also interesting to mention that the farmers belonged to small herd size perceived 'high cost of dry fodder' as constraint to extent of 71.08 per cent, whereas medium and large dairy farmers perceived the same constraint to the extent of about 44.00 per cent. The possible reason may be that small dairy farmers have to purchase the wheat straw from other farmers for feeding their buffalo, whereas most of the medium and large farmers, cultivate wheat and use the wheat straw as dry fodder to fed their buffalo.

It can be concluded from the study that majority of the dairy farmers perceived breeding and feeding constraints as serious level of constraints. The availability of poor quality of semen was regarded as major breeding constraint, which might be due to improper semen storage facility at AI centres/ veterinary hospitals. Long calving interval in buffalo and non-availability of elite bulls were also considered as the major breeding constraints. Among the feeding constraints high

Table 2. Item-wise constraints level of breeding practices

S. No	Items/Aspects	Dairy farmers Category											
		Small (n=83)			Medium (n=64)			Large (n=33)			Overall (n=180)		
		MS	MPS	RO	MS	MPS	RO	MS	MPS	RO	MS	MPS	RO
1	Non availability of A.I. facilities	1.77	59.04	VII	1.69	56.25	III	1.33	44.44	VI	1.66	55.37	V
2	Non availability of elite bulls	1.89	63.05	V	1.66	55.21	IV	1.91	63.64	II	1.81	60.37	III
3	Silent heat in buffaloes	2.02	67.47	III	1.31	43.75	VIII	1.48	49.49	V	1.67	55.74	IV
4	Inbreeding in buffaloes	1.80	59.84	VI	1.41	46.88	V	1.82	60.61	III	1.66	55.37	V
5	Long calving interval	2.13	71.08	II	2.17	72.40	II	1.61	53.54	IV	2.05	68.33	II
6	Poor quality of semen	2.52	83.94	I	2.78	92.71	I	2.64	87.88	I	2.63	87.78	I
7	Lack of trained A.I. facilitators	1.94	64.66	IV	1.34	44.79	VII	1.33	44.44	VI	1.62	53.89	VII
8	Timely availability of A.I. experts	1.73	57.83	VIII	1.36	45.31	VI	1.24	41.41	VIII	1.51	50.37	VIII

MS: Mean Score, MPS: Mean Percent Score, RO: Rank Order

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Table 3. Item-wise constraints level of feeding practices

S. No	Items/Aspects	Dairy farmers Category											
		Small (n=83)			Medium (n=64)			Large (n=33)			Overall (n=180)		
		MS	MPS	RO	MS	MPS	RO	MS	MPS	RO	MS	MPS	RO
1	Non availability of green fodder	1.92	63.86	VI	1.52	50.52	V	1.97	65.66	IV	1.78	59.44	V
2	High cost of dry fodder	2.13	71.08	III	1.33	44.27	VI	1.33	44.44	VI	1.70	56.67	VI
3	Non availability of seeds of HYV of fodder	2.06	68.67	V	1.94	64.58	IV	2.15	71.72	III	2.03	67.78	IV
4	High cost of concentrate	2.45	81.53	I	2.73	91.15	I	2.64	87.88	I	2.58	86.11	I
5	Lack of knowledge of buffalo feeding practices	2.11	70.28	IV	2.19	72.92	II	1.70	56.57	V	2.06	68.70	III
6	High cost of mineral mixture	2.16	71.89	II	2.06	68.75	III	2.27	75.76	II	2.14	71.48	II

MS: Mean Score, MPS: Mean Percent Score, RO: Rank Order

cost of concentrate, mineral mixture and lack of knowledge were the major constraints faced by the dairy farmers. Therefore, some sort of facilities like the bulls of improved breeds, namely Murrah/Nili Ravi should be arranged on community basis (at Village level) through Panchayat with the help of Government subsidy or collective efforts of the villagers, so that problems of inbreeding as well as non-availability of elite bulls may be solved. Moreover educational programmes should also be organized to create the awareness among the villagers/ buffalo farmers about improved breeding and feeding practices. Almost all categories of respondents perceived the high cost of concentrate and mineral mixture as the major feeding constraints. So these materials should be available at reasonable rates to the dairy farmers.

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Soil Physical Properties and Root Density of Wheat (*Triticum aestivum* L.) in Relation to Planting Techniques

Amandeep Singh Brar and U.S. Walia

Department of Agronomy
Punjab Agricultural University, Ludhiana-141004, India
E-mail: aman_pau@yahoo.com

Tillage practices have their own limitations, while the same performed with tractor and tillers has its distinct edge (Gurumurthy and Rao, 2006). Usually, the bulk density and penetration resistance of tilled soils decreases while repeated tillage with the farm machinery and tillage implements creates a compact layer underneath that restricts water flow and root penetration (Carter and Colwick, 1971). However, when tillage is reduced, soil porosity increases and often, surface sealing occurs which reduces the infiltration rate (Lindstrom and Onstad, 1984). Quantitative information on soil physical properties and root growth under differ tillage systems is inadequate and inconclusive particularly under paddy-wheat system. Therefore, an investigation was undertaken with the objective to study the effect of different wheat planting techniques on soil physical properties and root growth of wheat under paddy-wheat system.

The experiment was conducted at the experimental farm of the Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab (India). The treatments comprised of five planting techniques viz., conventional tillage, zero tillage, zero till sowing in standing stubbles, zero till sowing after partial burning (Farmers' practice) and bed planting. These treatments were replicated thrice. The soil of the experimental field was loamy sand in texture with sand, silt and clay 76.8, 9.3 and 13.8 per cent, respectively.

After harvesting paddy crop, field was ploughed twice with disc harrow and once with cultivator followed by planking in case of conventional tillage and bed planting. After pre-sowing irrigation again two ploughings followed by planking were given to facilitate the preparation of fine seed bed. The crop was directly sown in zero tillage treatments after rice harvest with sickle in 1.0 to 1.5 feet standing stubbles and after partial burning of rice straw. In case of bed planting treatment, beds were prepared with bed planter, which were 67.5 cm wide (37.5 cm bed top and 30 cm furrow). The sowing of wheat was done with tractor drawn zero till / ordinary drill as per treatment using seed rate of 100 kg ha^{-1}. Sowing of bed planting treatment was done with tractor drawn bed planter (2 rows bed^{-1}) using 75 kg seed ha^{-1}. Crop was raised with recommended package of practices.

For calculating the bulk density of soil, samples of undisturbed soil were taken before sowing and after harvest of wheat crop from 0-15, 15-30, 30-60 and 60-90 cm depths from the different plots. Soil strength was measured before sowing and after harvesting of wheat crop by using penetrometer from 0-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-35, 35-40, 40-45 and 45-50 cm soil depths from different plots. Water infiltration was measured before sowing and after harvesting of wheat crop with the help of double ring infiltrometers of 35 and 40 cm diameter and 28 cm height as described by Black (1965). Layer wise (0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm and 60-90 cm) soil core samples were taken with the help of root sampling pipe having internal diameter of 10 cm. The samples were excavated from the plant base at 110 days after sowing (DAS) when the wheat crop was at boot stage. The soil samples thus obtained were washed in thin nylon mesh of one mm sieve in running water. The washed roots were picked up and then dried at 60°C in an oven to get constant weight. The root density was expressed as weight of roots per unit volume of soil and calculated as follows.

$$\text{Root density (Kg m}^{-3}\text{ of soil)} = \frac{\text{Total root weight (oven dried) in particular depth increment (Kg)}}{\text{Total soil volume from which roots were collected (m}^3\text{)}}$$

Bulk Density

The mean values of two years for bulk density of 0-15 cm and 15-30 cm soil layers were lower than the initial values under all the planting techniques recorded after the harvest of wheat crop (Table 1). At 0-15 cm soil layer the least bulk density was recorded under bed planting followed by conventional tillage, zero till sowing in standing stubbles, zero till sowing after partial burning (farmers' practice) and zero tillage treatments. For 15-30 cm soil layer same trend was observed as that of 0-15 cm soil layer. The lower bulk density in bed planting and conventional tillage might be

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due to pulverization of soil caused by ploughing. Under zero till sowing in standing stubbles and after partial burning treatments, lower bulk density than zero tillage treatment might be due to addition of some rice stubbles. Tebrugge and During (1999) also reported lower bulk density in zero tillage with stubbles in the top layer due to existing mulch layer on the top layer. There was little change in the bulk density under all the treatments in lower layers (60-90 cm). Conventional tillage and bed planting recorded slight increase in bulk density in the lower layers as compared to zero till systems. This slight increase in bulk density under conventional tillage and bed planting treatments might be due to compaction created with farm machinery during farm operations. Ram (2006) also reported lower bulk density under bed planting and conventional tillage as compared to zero tillage treatments in top layers.

Penetration Resistance (Soil Strength)

The perusal of data presented in Table 2 showed that mean values of two years for penetration resistance were lower in conventional tillage and bed planting treatments followed by zero till systems, which recorded the maximum penetration resistance. After 25 cm up to 50 cm soil profile, under conventional tillage and bed planting treatments penetration resistance was more than that under different zero tillage systems which were almost similar in terms of penetration resistance because pulverization of soil with tillage was confined only up to the upper layers. In general, the penetration resistance recorded after wheat harvest was substantially lower in comparison to the initial values recorded before sowing of wheat. Under conventional tillage and bed planting treatments, lower penetration resistance in upper layers and higher penetration resistance under lower layers might be due to ploughing which caused pulverization in upper layers and compaction in lowers layers. Etana *et al.* (1999) also reported substantial increase in the penetration resistance below the plough layer in conventional tillage system.

Water Infiltration

The mean values of two years study presented in Table 3 revealed that at the starting time water infiltration was higher under bed planting and convention tillage treatments as compared to zero tillage treatments. Under bed planting and conventional tillage treatments infiltration rate was slightly lower than zero tillage treatments at 34th minute observational period. Slower water infiltration rate at this stage might be due to the presence of compact soil layer

Table 1. Bulk density (Mg m^{-3}) of soil before sowing and after harvest of wheat crop in relation to planting techniques (mean data of two years)

Soil depth (cm)	Initial	After harvest of wheat crop				
		Conventional tillage	Zero tillage	Zero till sowing in standing stubbles	Zero till sowing after partial burning	Bed planting
0-15	1.56	1.51	1.55	1.53	1.54	1.50
15-30	1.62	1.60	1.62	1.61	1.61	1.60
30-60	1.65	1.68	1.64	1.64	1.64	1.67
60-90	1.60	1.61	1.60	1.60	1.60	1.61

Table 2. Penetration resistance (deci MPa) of soil before sowing and after harvest of wheat crop in relation to planting techniques (mean data of two years)

Soil depth (cm)	Initial	After harvest of wheat crop				
		Conventional tillage	Zero tillage	Zero till sowing in standing stubbles	Zero till sowing after partial burning	Bed planting
0-5	12.52	10.05	12.14	10.81	11.38	9.67
5-10	15.55	12.33	14.98	13.65	14.60	11.57
10-15	16.88	13.27	16.50	16.12	15.93	13.84
15-20	22.00	14.22	21.43	21.05	21.43	15.36
20-25	22.57	20.48	21.24	21.24	21.43	21.24
25-30	20.67	22.57	19.72	19.72	19.34	22.19
30-35	18.77	23.36	17.83	17.82	17.82	22.95
35-40	18.01	24.46	17.07	17.26	17.45	23.93
40-45	16.50	18.96	16.12	16.31	16.12	18.58
45-50	14.41	15.93	14.41	14.22	14.60	15.93

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created by traffic of farm machinery. Overall, the higher cumulative water infiltration was observed under bed planting closely followed by conventional tillage and then zero till sowing in standing stubbles, zero till sowing after partial burning (farmers' practice) and zero tillage treatments. Cumulative water infiltration was slightly higher after the harvest of wheat crop than that before sowing of the wheat. The results are in line with Aggarwal and Goswami (2003) and Ram (2006).

Root Density of Wheat

Root development pattern plays an imperative role in uptake of water and nutrients that eventually influence the growth and yield of crop. The observations recorded regarding root density of wheat at 110 DAS (Table 4) revealed that root density varied between different soil layers. The maximum root density was observed at 0-15 cm soil layer. Subsequently it decreased drastically. Among the different planting techniques, the maximum root density was recorded at 0-15 cm soil depth with bed planting followed by conventional tillage, zero till sowing in standing stubbles, zero till sowing with partial burning and zero tillage treatments. At 15-30 cm soil layer similar trend was observed as that of 0-15 cm soil layers. Thereafter, root density in the lower soil layers was lower in bed planting and conventional tillage than zero tillage systems. At the lower most observational layer (60-90 cm) zero till sowing treatments registered almost equal values of root density and these values were higher than that of bed planting and conventional tillage treatments. Total roots were higher with bed planting followed by conventional tillage, zero till sowing in standing stubbles, zero till sowing after partial burning and zero tillage treatments. The higher root density in the top layer in bed planting and conventional tillage indicated that pulverization, lesser penetration resistance and lower bulk density encouraged better root growth. In the lower layers compaction of soil restricted the root growth under tilled plots. Higher root proliferation in the top 0-30 cm soil layer and restricted root growth under lower layer in tilled soils was also reported by Ehlers *et al.* (1983).

From the above discussion it can be summarized that in conventional tillage and bed planting treatments, lower bulk density and soil strength were observed in the surface layer due to pulverization caused by tillage as a result of

Table 3. Cumulative water infiltration (cm) before sowing and after harvest of wheat crop in relation to planting techniques (mean data of two years)

Time interval (min)	Cumulative time (min)	Initial	After harvest of wheat crop				
			Conventional tillage	Zero tillage	Zero till sowing in standing stubbles	Zero till sowing after partial burning	Bed planting
2	2	0.9	1.6	1.0	1.3	1.1	1.9
2	4	1.6	3.0	1.8	2.2	1.9	3.4
5	9	2.5	3.1	2.7	3.3	2.9	5.0
5	14	3.2	5.6	3.5	4.1	3.7	6.1
10	24	4.3	7.0	4.7	5.3	4.8	7.6
10	34	5.2	7.9	5.7	6.5	6.0	8.6
30	64	7.4	10.3	8.1	9.0	8.5	10.9
30	94	9.3	12.3	10.2	11.2	10.6	13.0
60	154	12.1	15.2	13.2	14.3	13.5	15.9
60	214	14.1	17.3	15.4	16.6	16.0	18.0

Table 4. Root density (Kg m-3) of wheat at 110 days after sowing as influenced by various planting techniques (mean data of two years)

Soil depth (cm)	Conventional tillage	Zero tillage	Zero till sowing in standing stubbles	Zero till sowing after partial burning	Bed planting
0-15	1.039	0.797	0.931	0.909	1.096
15-30	0.683	0.583	0.643	0.626	0.756
30-45	0.318	0.342	0.365	0.349	0.340
45-60	0.132	0.144	0.162	0.157	0.139
60-90	0.062	0.075	0.080	0.078	0.067
Total	2.234	1.939	2.180	2.118	2.396

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which higher water infiltration at initial stages and higher root density in upper layers were also observed under these treatments. However, in lower layers values of bulk density and soil strength were higher and water infiltration and root density were lower in conventional tillage and bed planting than zero tillage system due to compaction created by traffic of farm machinery. Among the zero tillage treatments, due to presence of straw as mulch in zero till sowing in standing stubbles and after partial burning favoured physical properties as compared to zero tillage alone. So, crop residue mulch should be preferred than clean cultivation. Conventional tillage and bed planting improves soil physical conditions in upper layer, whereas, reverse occurs in deeper layers. So, where more farm machinery is used to prepare fields, deep ploughing should be done after few years to break the compact layer beneath the plough layer.

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Productivity of Wheat (*Triticum aestivum* L.) Planted with Happy Seeder as Influenced by Split Application of Nitrogen

Khushwant Singh, J. S. Kang and Avtar Singh*

Department of Agronomy, Punjab Agricultural University, Ludhiana-141 004, Punjab, India
**E-mail: avtar_bimbraw@yahoo.com*

Wheat (*Triticum aestivum* L.) occupies the prime position among the food crops in India. Wheat is the second most important food crop after rice and has played a very vital role in increasing and stabilizing the food production of the country (Bhat and Mahal, 2006). It is grown on 28.15 mha with production of 75.81 MT and per hectare yield of 2708 kg during 2007-2008 (Anonymous 2008). India has an ever growing population needing food. Population of India is predicted to reach 1.3 billion by 2020 AD and wheat demand to 96 MT (Hobbs and Morris 1996). So, there is need to increase in the productivity of wheat. In this connection adequate tillage and fertilization would be important measures. Wheat is the major crop of India and mainly grown with conventional tillage after rice. The conventional system involves intensive tillage which enhances the oxidation as well as burning of crop residue. Burning residue causes great damage to environment and substantial loss of plant nutrients (especially N and S) and organic carbon also occurs during burning of crop residue, which has important implications for soil health (Singh and Singh 2009). The number of ploughings and clean cultivation does not increase the yield but increase the cost of production and also causes the degradation of environment. Now a days, the researchers are interested in different alternative tillage system to cope with the limited natural resources to reassess current management practices for wheat production planted with happy seeder. Along with different planting techniques optimum application of fertilizers is important to increase the yield of wheat crop. Nitrogen is an important essential plant nutrient whose deficiency in soils is wide spread. Plants normally contain 1-5 per cent N by weight (Tisdale *et. al.* 1995). It has been observed that nitrogen fertilization and its appropriate application time not only improve the yield of both bread and durum wheat but also affect the quality of their grain. Split application of nitrogen can minimize volatilization or immobilization losses. Information on nitrogen levels and their split application in wheat planted with happy seeder is necessary to maximize yield. This study was undertaken to determine the effects of levels and split application of nitrogen treatments on the productivity of wheat planted with happy seeder.

This study was carried out at Punjab Agricultural University, Ludhiana to determine the influence of nitrogen rates and its split application on the productivity of wheat (*Triticum aestivum* L.) planted with happy seeder. Ludhiana representing the Indo-Gangetic alluvial plains is situated at the 30°56' N latitude and 75°52' E longitude and at an altitude of 247m above mean sea level. It is characterized by subtropical semi-arid type of climate with hot and dry summer (mid April to end of June), hot and humid summer monsoon period (early July to end of September), mild winter (October to November) and very cold winter (December to the end of February). The soil samples from 0-15 cm depth were collected before initiating the experiment. The mechanical and chemical analysis of soil samples was done to determine the texture and fertility of field experiments. The soil of experimental field was sandy loam in texture contains sand, silt and clay of 80.5, 10.5 and 9.0 %, respectively. The soils of the field were neutral in reaction, low in organic carbon and available N (165.9 kg ha^{-1}), medium in available P (20.3 kg ha^{-1}) and K (178.8 kg ha^{-1}). The experiment was carried out in the split plot design with nitrogen (N) rates (100, 125 and 150 kg ha^{-1}) in the main plots and split application treatments as 1/2 N at sowing, 1/2 N before 1st irrigation (T1), 1/2 N at sowing, 1/2 N after 1st irrigation (T2), 1/3 N at sowing, 1/3 N before 1st irrigation and1/3rd N before 2nd irrigation (T3), 1/3 N at sowing, 1/3 N after 1st irrigation and 1/3 N after 2nd irrigation (T4), 1/2 N at sowing, 1/4 N before 1st irrigation and 1/4 N before 2nd irrigation (T5), 1/2 N at sowing, 1/4 N after 1st irrigation and 1/4 N after 2nd irrigation (T6), 1/4 N at sowing 1/4 N before 1st irrigation and 1/2 N before 2nd irrigation (T7), 1/4 N at sowing 1/4 N after 1st irrigation and 1/2 N after 2nd irrigation (T8) in the sub plots and these treatments were repeated three times. The crop was directly sown in the field by happy seeder without any preparatory tillage by spreading the loose straw of combined harvested rice. The wheat cv. PBW 550 was sown on November 14,2009 by happy seeder using 100 kg seed ha^{-1} in rows keeping gross

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plot size measuring 6m x 2.5 m. N fertilizer was applied as per treatment. Full dose of phosphorus and muriate of potash was applied at sowing. Experimental plots were given post emergence spray of 2, 4-D @ 625g in 500 liters of water per hectare at 40 days after sowing. The crop was harvested manually on April 13, 2010.

Dry matter accumulation (DMA) is the total accumulation of photosynthates formed and total nutrient uptake by the plant up to stipulated growth period (Table 1). DMA per unit area is directly proportional to number of tillers and plant height. Application of N at different rates significantly increased the DMA at maturity. However, DMA increased with the increase in N up to the highest level of 150 kg ha^{-1} that was at par obtained with 125 kg N $ha^{-1}$and significantly superior to 100 kg N ha^{-1}. N application at different time had significant effect on DMA. The DMA was and significantly higher over all treatments of split application except T7. The effective tillers per meter square were found maximum where higher dose of N was applied *i.e.* 150 kg ha^{-1} that was significantly higher than the other two rates of N. There was no significant affect due to split application of N on effective tillers per meter square at maturity. Similarly, grains per ear and 1000-grain weight were not affected by nitrogen rates and time of N application. Harvest index was not affected by various N rates. However, it was significantly influenced by time of N application. The highest harvest index was observed in T8 which was at par with T4 and T5 treatment of split application of N.

There was no significant affect on grain yield of crop with the addition of N at different rates (Table 2). However, the higher grain yield was recorded with 150 kg Nha^{-1} that was 5.2 and 12.1 per cent higher than 125 and 100 kg N ha^{-1}, respectively. The time of N application showed significant effect on the grain yield. The application of N in three equal splits (T3) produced significantly higher grain yield that was at par with T7 and T8 treatments as compared to other treatments comprising of two or three splits. The higher grain yield under T3 might due to the more efficiently utilization of N with the application of 1/3 at sowing and remaining in two equal splits before first and second irrigation. Khademi (1998) also reported that increasing the number of split applications increased grain yield. Similarly, El Desoky and El Far (1999) and El Desoky *et al.* (2000) reported that bread wheat with 2 splits of N at 3 weeks after sowing and at stem elongation or 3 splits of N at 3 weeks after sowing, at stem elongation and heading produced the greatest straw and grain yield, and the highest N use efficiency. The interaction effects on grain yields were found significant due to N rates and timings of N application. The N application at 125 kg ha^{-1} ; 1/4 N at sowing 1/4 N after

Table 1. Effect of different nitrogen treatments on growth and yield attributing characters of wheat

Treatment	DMA at maturity (q ha^{-1})	Effective tillers m^2	Grains ear^{-1}	1000-grain weight (g)	Harvest index
Nitrogen (kg ha^{-1})					
100	65.8	199.1	51.9	47.7	40.9
125	72.5	199.4	51.9	48.6	40.9
150	76.1	211.0	52.7	48.9	39.5
CD (p=0.05)	4.45	4.74	NS	NS	NS
Split application of nitrogen					
½ N at sowing, ½ N before 1st Irrigation (T1)	65.0	199.1	50.8	50.0	38.9
½ N at sowing, ½ N after 1st Irrigation (T2)	69.0	200.8	52.5	48.3	39.9
1/3rd N at sowing, 1/3rd N before 1st irrigation and 1/3rd N before 2nd irrigation (T3)	80.0	212.9	52.3	47.4	41.0
1/3rd N at sowing, 1/3rd N after 1st irrigation and 1/3rd N after 2nd irrigation (T4)	72.4	201.6	53.0	47.8	41.1
½ N at sowing, 1/4th N before 1st irrigation and 1/4th N before 2nd irrigation (T5)	72.5	202.1	51.3	48.8	41.2
½ N at sowing, 1/4th N after 1st irrigation and 1/4th N after 2nd irrigation (T6)	66.1	198.4	52.0	48.2	38.8
½ N at sowing 1/4th N before 1st irrigation and ½ N before 2nd irrigation (T7)	76.2	203.8	51.7	48.4	39.8
1/4th N at sowing 1/4th N after 1st irrigation and ½ N after 2nd irrigation (T8)	70.6	206.4	53.8	48.6	42.9
CD (p=0.05)	5.23	NS	NS	NS	1.8

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Table 2. Effect of different nitrogen treatments on grain, yield of wheat

Treatments	Split application of N								
	Grain yield (q ha^{-1})								
N (kg ha^{-1})	T1	T2	T3	T4	T5	T6	T7	T8	Mean
100	26.0	27.8	33.7	24.6	27.2	20.0	27.4	29.1	27.0
125	24.0	26.0	32.0	26.6	29.3	29.6	31.3	34.0	29.1
150	31.8	28.7	32.6	28.6	32.8	27.3	32.3	31.1	30.7
Mean	27.3	27.5	32.7	26.6	29.8	25.7	30.4	31.4	
CD (p=0.05)	N- NS; Split application of N- 2.55; N x split application of N- 4.41								

1st irrigation and 1/2 N after 2nd irrigation gave higher grain yield that was at par with 100 kg N ha^{-1} ; 1/3 N at sowing, 1/3 N before 1st irrigation and1/3rd N before 2nd irrigation, 125 kg N ha^{-1}; 1/3 N at sowing, 1/3 N before 1st irrigation and1/3rd N before 2nd irrigation, 150 kg N ha^{-1}; 1/3 N at sowing, 1/3 N before 1st irrigation and1/3rd N before 2nd irrigation, 150 kg N ha^{-1} ; 1/2 N at sowing, 1/4 N before 1st irrigation and 1/4 N before 2nd irrigation, 125 kg N ha^{-1} ;1/2 N at sowing, 1/4 N after 1st irrigation and 1/4 N after 2nd irrigation, 125 kg N ha^{-1}; 1/4 N at sowing 1/4 N before 1st irrigation and 1/2 N before 2nd irrigation, 150 kg N ha^{-1} ; 1/4 N at sowing 1/4 N before 1st irrigation and 1/2 N before 2nd irrigation and 150 kg N ha^{-1} ; 1/4 N at sowing 1/4 N after 1st irrigation and 1/2 N after 2nd irrigation than the other treatment combinations. The overall yield levels were low due to the rainfall at the time of sowing which resulted in poor population of crop under no-till conditions.

On the basis of the results of this investigation, the N application at 100 kg N ha^{-1} ; 1/3 N at sowing, 1/3 N before 1st irrigation and1/3rd N before 2nd irrigation to the happy seeder sown wheat is found to be optimum to get the maximum seed yield.

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Effect of Different Soil Potting mixtures on the Germination and Growth of *Desi* Mango (*Mangifera indica* L.) Stones Grown in Polythene Bags

Sukhjit Kaur

P.A.U., Regional Research Station,Gurdaspur-143521, Punjab, India
E-mail : sukhi.rose@gmail.com

The seedlings raised in nursery on good media will ensure better establishment and growth when planted to the main field. The production of planting stock of superior quality is the pre-requisite for plantation of an orchard. The potting mixture should have enough nutrients, good water holding capacity and drainage to ensure better growth of seedlings (Noble,1993).There is necessity of reducing the production cost of planting stock by utilizing locally available material. There is increasing interest in the potential use of vermicompost as plant growth media and soil amendments for enhancing the plant growth and development as reported by several workers. These are products of a non-thermophilic bio-degradation of organic materials through interactions between earthworms and microorganisms. In vermicompost, compared to conventional compost, accelerated bio-oxidation of organic matter is achieved mostly by high density earthworms populations (Domi'nguez *et al.*,1997 and Subler *et al.*, 1998). Vermicomposts are typically finely divided peat-like materials with high porosity, aeration, drainage and water holding capacity (Edwards and Burrows,1988) necessary for better plant growth and development . Vermicompost can be used as a potting mixture for horticultural crops. Therefore, in the present study different soil potting mixtures were used to ascertain their effects on germination and growth of *desi* mango stones grown in polybags.

The present investigation was carried out at Punjab Agricultural University, Regional Research Station,Gurdaspur during the years 2010-11 and 2011-12. The healthy disease free stones of *desi* mango were collected in the month of July and sown in the 1st week of August in black polythene bags (40cmx25cm size and 150-200 gauge thickness) containing different soil potting mixtures viz. Soil: Sand (1:1), Soil: Sand: FYM (1:1:1), Soil: FYM (1:1), Soil:Sand: Vermicompost (1:1:1), Soil: Vermicompost (1:1), Sand:Vermicompost (1:1) and sandy loam soil (control) The data on germination percentage, number of days taken for germination, seedling height (cm), seedling girth (cm),number of leaves and root length (cm) were recorded. The root length is recorded with measuring scale. The data was analysed statistically according to Randomized Block Design (RBD).

The germination percentage of mango stones was significantly influenced by potting mixtures (Table1). There was a significant difference observed in the days taken for initiation of germination among all the treatments and the earliest germination was recorded in T_4 (17.10 days) followed by T_2. The germination percentage was highest in T_4 (85.23%) followed by T_2 and significantly different from all other treatments. The T4 treatment was found to be best followed by T_2 with regard to germination behavior, as these media have suitable physical properties and good water holding capacity that supports the germination of mango stones. Vermicompost is reported to have bioactive principles which are considered to be beneficial for root growth and this has been hypothesized to result in greater root initiation, increased biomass, enhanced growth and development (Bachman and Metzger, 2008) and also balanced composition of nutrients (Zaller, 2007). Vigour index of seedlings indicated the overall performance of seeds and seedlings. The significant differences were observed among the different treatments with regard to seedling growth parameters and maximum seedling height was observed in T_4 (75.50cm) followed by T_2. Nutrients in vermicompost are present in readily available forms for plant uptake e.g. nitrates, exchangeable P, K, Ca and Mg (Edwards and Burrows,1988). Buckerfield and Webster (1998) and Venkatesh *et al.* (1999) reported that yields of grapes were significantly greater with vermicompost application due to more plant growth and development. Similar trend was noticed in strawberry (Singh *et al.*, 2008) and pineapple (Baldatto *et al.*, 2009). Vermicompost are comprised of large amounts of humic substances, some of the effects of which on plant growth are similar to those of soil-applied plant growth regulators (Muscolo *et al.*,1999). Similarly the seedling girth, number of leaves and root length were significantly higher in T_4 (8.20cm,28.20 and 26.50cm respectively) followed by T_2. Study conducted by Barve (1992)

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Table1. Effect of different soil potting mixtures on the germination and growth of *desi* mango stones grown in polythene bags

Potting Mixtures	Germination percentage	Days for germination	Seedling height (cm)	Seedling girth (cm)	Number of leaves	Root length (cm)
Soil:Sand (T_1)	30.3	25.0	25.5	2.50	12.0	9.5
Soil:Sand:FYM (T_2)	70.4	20.0	65.5	6.23	22.5	21.0
Soil:FYM (T_3)	38.7	24.0	32.4	3.00	13.1	11.0
Soil:Sand:Vermicompost (T_4)	85.2	17.1	75.5	8.20	28.2	26.5
Soil:Vermicompost (T_5)	58.3	21.0	48.5	4.63	18.2	16.5
Sand:Vermicompost (T_6)	45.6	22.5	40.2	3.50	16.2	13.0
Soil (Control)	25.5	27.3	20.2	2.00	10.2	8.0
CD (p=0.05)	4.09	2.06	2.77	0.65	2.54	2.51

reported the improved growth of grape plants with sole application of vermicompost. The vermicompost (N-1.9%, C:N ratio-13.6%, P-2.0%, K-0.8%, Zn-100ppm, Cu-48ppm and Mn-500ppm) contains more amount of nutrients than FYM (well decomposed with N-0.5%, P_2O_5-0.2% and K_2O-0.5%)making it to stand first and sand will provide porosity and drainage to the growth medium and helps in better stand for germination and seedling growth.

The present study indicate that Soil: Sand: Vermicompost (1:1:1) potting mixtures was found to best growth media for enhancing the growth of the mango seedlings.

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Genotype x Environment Interaction for Grain Yield and Component Traits in Chickpea (*Cicer arietinum* L.)

Vijay Prakash

AICRP on Chickpea,

Agricultural Research Station, SK Rajasthan Agricultural University, Sriganganagar – 335 001, Rajasthan, India
E-mail: drvijayprakash1967@yahoo.co.in

The development of cultivars or varieties, which can be adapted to a wide range of diversified environments, is the ultimate goal of plant breeders in a crop improvement program. The adaptability of a variety over diverse environments is usually tested by the degree of its interaction with different environments under which it is planted. A variety or genotype is considered to be more adaptive or stable one if it has a high mean yield but a low degree of fluctuation in yielding ability when grown over diverse environments. The genotype x environment interaction was studied by different researchers in various crops (Prakash 2006; Jain and Pandya 1988; Zubair and Ghafoor, 2001). The stability parameters have also been studied in grain legumes for measuring phenotypic stability (Bakhsh *et al.*, 1995; Tiwari *et al.*, 2000; Popalghat *et al.*, 2001), but still it is very important information that should be available for the forth-coming chickpea varieties. Therefore, present investigation was aimed to evaluate some genotypes of chickpea for their yield stability under different environments.

The experimental material consisted of thirty eight advance fixed genotypes derived from various crosses of chickpea raised simultaneously during *Rabi* season of 2010-11 at Agricultural Research Station, Sriganganagar (Rajasthan). The experiment was conducted in Complete Randomize Block Design comprising of three replications. Data were recorded on ten randomly selected plants for 100-seed weight (g), pods per plant and plant height (cm). Grain yield (kg ha^{-1}), days to 50 % flowering and days to maturity were recorded on plot basis. Stability parameters for different characters were computed using the regression approach of Eberhart and Russell (1966). Different genetic parameters such as variability, heritability and genetic advance were estimated following Johnson *et al.* (1955).

Pooled analysis of variance revealed significant differences among the genotypes for all the characters. Further, variance due to environment (linear) except for days to maturity indicated that performance of the genotypes could be predicted. The variance due to G x E was significant for all the traits except days to 50% flowering and days to maturity (Table 1). Stability parameters for different characters are summerised in Table 2. The genotypes GNG 2065, GNG 2085, GNG 2083, GNG 2084, GNG 2070, GNG 2078, GNG 2071, GNG 2076, GNG 2089, GNG 2088, GNG 1581 and GNG 469 have showed higher *per se* performance for grain yield along with non significant $S^2di=0$ value and regression coefficient near to one. The genotypes GNG 2086

Table 1. Analysis of variance (MS) for stability for grain yield and contributing traits in chickpea

Source of variation	d.f.	Grain yield (kg ha^{-1})	100-seed weight (g)	Pods per plant	Days to 50 % flowering	Days to maturity	Plant height (cm)
Varieties	37	130736.65**	7.363*	3.933**	79.273**	55.067**	90.030*
Environment + (Variety x Environment)	114.216*						
Environments	76	919786.74**	9.118**	300.746**	120.401**	2.473	
Variety x Environment	2	32132188**	196.257*	11364.390**	3706.098**	2.961	2110.578**
Environments (Linear)	74	76208.21**	4.060**	1.728**	23.490	2.460	60.261**
Variety x Environment (Linear)	1	64264376**	392.514**	22728.790**	7412.195**	5.922	4221.156**
Pooled deviation	37	89107.91**	5.861**	1.407*	21.859	2.449	69.267**
Pooled Error	38	41642.49++	2.200++	0.995++	24.460++	2.406++	39.905++
	222	24832.32	0.169	0.107	4.119	0.043	3.065

*, "significant against pooled deviation M.S. at 5% and 1% level, respectively;
+, ++ significant against pooled error M.S. at 5% and 1% level, respectively

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Table 2. Estimates of stability parameters for different traits in chickpea

Genotype	Grain yield (kg/ha)			100-seed weight (g)			Pods per plant			Days to 50 % flowering			Days to maturity			Plant height (cm)		
	x	bi	S²di	x	bi	S²di	x	bi	S²di	x	bi	S²di	x	bi	S²di	x	bi	S²di
GNG 2054	2917.6	1.11	3889.3	13.4	2.28	-0.03	63.7	1.71	42.3**	94.2	1.50	-0.10	141.3	0.97	1.6**	61.1	1.33	30.5**
GNG 2055	3008.6	0.96	-23728.2	12.0	-0.67	0.15*	64.3	0.16	38.9**	92.8	1.12	6.84**	141.2	0.98	1.6**	63.8	1.49	109.3**
GNG 2056	2988.8	1.06	70581.2*	11.3	2.00	0.04**	50.7	0.15	-0.8	93.7	0.81	0.03	140.3	0.97	-0.1	64.3	0.60	-2.3
GNG 2057	3058.6	0.91	1506.9	11.0	1.17	0.15*	55.8	0.98	18.0**	93.2	0.75	5.58**	140.3	0.96	0	61.4	1.38	25.3*
GNG 2058	3013.3	0.99	13607.4	14.3	4.77	50.49**	64.2	2.97	23.5**	93.0	0.53	5.13**	140.2	1.00	0	64.0	1.55	29.5**
GNG 2059	2944.7	0.72	-11068.0	16.2	0.70	0.81*	57.7	0.84	0.7	92.3	2.10	2.39**	140.2	1.02	-0.1	62.8	1.63	18.6*
GNG 2060	2823.8	0.8	-5335.9	15.7	-1.05	1.07**	61.4	-0.05*	-2.8	93.6	1.03	0.13	140.0	0.95	0.9**	58.1	1.06	1.80
GNG 2061	2723.2	1.03	-23680.1	12.8	-0.09	-0.04	61.7	-0.05	29.4**	93.4	0.55	-0.15	139.6	0.89	0.5*	60.6	1.28	57.6**
GNG 2062	2499.9	0.18	81645.1*	16.0	3.50	1.57**	56.8	-0.31	7.6	92.0	1.38	0.26	139.9	0.91	0.4*	73.4	0.93	-4.1
GNG 2063	2829.0	0.34	-24114.2	14.6	1.34	-0.04	59.3	0.13	111.6**	89.9	1.45	9.77**	138.4	0.93	-0.1	58.2	1.00	8.9
GNG 2064	3431.8	1.27	215273.1**	18.4	-1.46	1.65**	63.8	0.79	91.0**	90.8	1.64	7.60**	139.8	0.95	1.7**	65.3	1.65	12.4
GNG 2065	3405.8	1.22	6850.8	14.9	-0.52	0.10	61.7	1.83	146.7**	94.6	0.03	0.79*	139.7	0.94	-0.1	61.1	1.01	-2.7
GNG 2066	3190.7	0.77	5569.1	12.7	0.26	-0.00	71.4	0.13	6.9	94.2	-0.28	0.00	139.6	0.96	1.0**	62.9	1.02	6.6
GNG 2067	3120.8	1.22	17939.7	15.4	2.68	2.66**	61.1	0.98	10.2*	94.2	0.00	0.35	139.7	0.98	4.0**	70.4	1.00	-4.3
GNG 2068	3185.8	1.21	238766.3*	13.0	1.55	0.57**	65.0	0.22	-0.6	94.6	0.27	1.13**	139.2	1.02	0.1	64.8	0.25	1.7
GNG 2069	3225.2	1.24	-18593.8**	19.6	2.42	0.09	62.6	1.41	206.3**	94.9	-0.11	1.10**	139.3	1.05	4.7**	68.1	0.73	-0.10
GNG 2070	2955.3	0.91	-781.3	19.7	-10.03	6.08**	57.4	1.60	14.6*	93.6	2.08	1.63**	139.9	1.00	1.1**	66.9	0.71	26.7**
GNG 2071	3265.7	1.19	33316.3	22.7	-1.27	1.82**	63.9	0.84	-1.1	91.0	1.28	3.14**	138.8	1.00	-0.1	72.7	0.93	-4.2
GNG 2072	2921.9	1.07	79342.7	22.6	1.79	-0.04	54.6	1.69	-2.3	94.4	0.64	0.63*	139.2	1.01	1.8**	73.1	1.15	-4.4
GNG 2073	2777.3	0.98	310670.9	19.3	2.53	0.48**	54.4	1.59	2.3	95.8	0.64	0.63*	139.8	1.00	9.0**	70.9	0.62	-4.2
GNG 2074	2660.0	0.93	8090.4	17.8	4.64	1.88**	57.6	1.09	-2.2	96.6	0.14	1.49**	139.2	1.02	0.1	71.1	1.06	1.8
GNG 2075	2865.0	0.79	5371.9**	19.1	4.51	-0.01	61.4	0.54	2.1	95.1	-0.36*	-0.11	138.6	1.01	1.4**	66.1	0.54	-4.1
GNG 2076	3161.1	1.08	2064.8	17.7	3.50	0.05	61.6	0.79	46.9**	95.3	-0.31	0.41	139.6	1.05	2.0**	70.4	0.83	10.2
GNG 2077	2960.0	0.93	-24120.5*	21.8	5.20	0.25**	56.0	0.40	262.0**	95.8	0.03	-0.10	141.4	1.08	0.0	69.8	1.15	85.1**
GNG 2078	3250.4	1.14	26024.6	21.2	2.63	0.70**	54.9	1.78	118.4**	93.3	1.99	1.49**	141.6	1.08	-0.1	70.1	1.40	4.4
GNG 2079	2659.0	1.29	364491.4	28.1	7.34	0.38**	49.7	1.76	5.5	93.7	1.58	0.02	141.1	1.11	0.1	77.1	1.20	94.0**
GNG 2080	2975.2	1.03	-23115.4	22.4	8.86*	0.01	53.1	1.34	-2.9	92.6	1.08	0.32	141.3	1.07	-0.1	72.0	0.99	30.2**
GNG 2081	3270.4	0.92	94968.8	20.5	-0.53	0.04	67.3	1.04	149.3**	91.7	1.42	3.72**	140.9	1.04	1.2**	73.6	0.82	74.1**
GNG 2082	3003.1	1.08	31693.1	21.0	-3.85	1.62**	60.3	1.79	-1.5	92.3	1.69*	-0.15	140.6	0.99	2.1**	72.1	1.40	-2.1
GNG 2083	3156.6	1.07	18640.3	24.7	1.10	3.71**	69.4	0.84	-2.6	91.3	1.58	0.02	140.0	1.01	2.0**	65.4	0.90	-4.4
GNG 2084	3011.0	1.07	44412.9	20.6	1.52	0.26**	60.7	2.36	234.0**	91.1	1.50	0.06	140.2	1.01	9.5**	75.4	1.03	11.7
GNG 2085	3280.2	0.96	13186.6	18.3	2.44	0.74**	68.1	-0.79	53.8**	91.3	1.71	2.36**	139.3	0.97	10.2**	62.4	0.85	-3.3
GNG 2086	3030.6	1.25	-18110.1	20.5	0.60	0.75**	60.2	1.97	105.8**	93.2	1.02	2.46**	139.4	1.04	7.8**	71.1	0.67	28.1**
GNG 2087	3284.7	1.23	-19432.2	25.9	1.39	0.58**	69.2	1.48	19.5**	91.9	1.44	1.20**	140.4	1.04	3.4**	75.4	1.00	74.9**
GNG 2088	3083.8	1.06	-14905.9	20.6	-2.59	-0.01	65.6	1.44	27.0**	92.0	1.88	9.66**	140.9	1.05	0.7**	67.8	0.76	39.4**
GNG 2089	3079.0	1.00	-17101.5	23.4	4.77	-0.04	65.3	0.75	3.7	93.1	1.91	1.36**	139.9	0.97	0.2	72.4	1.11	-0.3
GNG 1581	3141.2	1.07	-23982.9	13.0	-2.97	2.39**	64.9	0.91	-2.3	92.2	0.37	5.63**	140.6	0.98	0.6*	63.4	0.52	8.0
GNG 469	3037.8	0.91	-22969.5	19.3	-12.44	8.86**	60.8	0.89	22.4**	91.4	1.94	0.43	140.7	1.02	2.6**	71.4	0.46	10.9

*, ** significant at 5% and 1% level, respectively

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Table 3. Estimates of mean, GCV, PCV, heritability and genetic advance for different traits in chickpea

Trait	Mean ± SEm	GCV (%)	PCV (%)	h^2 (bs) (%)	GA
Grain yield (kg/ha)	3031.49 ±120.22	61.11	61.34	99.2	125.40
100-seed weight (g)	18.19 ± 0.85	20.29	20.82	95.0	40.74
Pods per plant	60.99 ± 2.53	11.91	12.61	89.2	23.16
Days to 50 % flowering	93.16 ± 0.62	2.50	2.59	93.3	04.98
Days to maturity	140.06 ± 0.82	10.11	10.13	99.7	20.79
Plant height (cm)	67.67 ± 1.98	13.33	13.65	95.4	26.83

PCV= Phenotypic coefficient of variance, GCV= Genotypic coefficient of variance, h^2 (bs) = Heritability in broad sense and GA= Genetic advance as percentage of mean

and GNG 2087 were found adapted to favourable environment as regression coefficient was more than unity for these genotypes. Although, the genotypes GNG 2064 and GNG 2069 have also showed high *per se* performance for grain yield but significance of deviation from regression indicated that these genotypes may not exhibit the same level of performance over all the environments. Estimates of stability parameters revealed that no single genotype was stable for all the traits studied. The stability parameters indicated that genotype GNG 2065 was the most stable genotype among the group as it showed good and desired *per se* performance along with regression coefficient around unity and non-significant S^2d_i values for grain yield as well as other traits like days to maturity and plant height. For 100-seed weight also it showed non significant value for deviation from regression. As far as the individual parameter is concerned the genotypes GNG 2063 for 100- Seed weight; GNG 2074 and GNG 1581 for pods per plant; GNG 2060 and GNG 2080 for days to 50% flowering; GNG 2057, GNG 2058, GNG 2059, GNG 2068, GNG 2074, GNG 2089, GNG 2077, GNG 2078, GNG 2079 and GNG 2080 for days to maturity and GNG 2062, GNG 2063, GNG 2066, GNG 2067, GNG 2074, GNG 2084 and GNG 2089 for plant height were found stable exhibiting non significant $S^2di=0$ value and regression coefficient near to unity.

A thorough understanding of the variations among cultivars in their response to environments would further improve the probability of predicting and identifying cultivars with superior attributes. Also suitable selection strategies to accommodate the G x E interactions need to be developed. The highest phenotypic coefficient of variation (PCV) was observed for grain yield followed by 100-seed weight and plant height. The genotypic coefficient of variation (GCV) was followed by same trend as PCV however, that in general PCV values were higher than GCV values for all the traits suggesting the influence of environmental forces on the expression of these traits (Table 3). All the characters showed high heritability, the height being for days to maturity flowed by grain yield, plant height, 100-seed weight, days to 50% flowering and pods per plant. High GA values together with high heritability estimates such as for grain yield and 100 seed weight indicated that substantial improvement for these traits could be achieved through direct selection.

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Indian Journal of Ecology

Influence of Topographical Aspect and Tillage Practices on Kaunch (*Mucuna pruriens*)

C. S. Sanwal[1], Sushma[2], Raheel Anwar Lone[3*], P. A. Khan[4], K. S. Pant[5] and S. D. Bhardwaj[6]

[1]*Indian Forest Service,* Mussoorie Forest Division-*248 179, Dehradun* (U.A), India
[2]*Department of Forestry, Wildlife and EVS, GGV, Bilaspur, (C.G) - 495 009, India*
[3]*Department of Forestry and Natural Resources, PAU, Ludhiana, Punjab - 141 004, India*
[4]*Faculty of Forestry, SKUAST Shalimar, Kashmir-191 121 (J & K), India*
[5]*Department of Silviculture and Agroforestry,* YSPUHF, *Nauni, Solan- 173 032 (H.P), India*
[6]*Sai Niwas 33 Scientist Colony Post Box Shamti, Solan-173212 (H.P), India*
**E-mail: raheelgreenwoods786@gmail.com*

Mucuna pruriens is an annual, half woody, twining herb, found almost all over India and in Andman and Nicobar islands. The genus thrives best under warm, moist conditions, below 1500 m above sea level (amsl), and in areas with plentiful rainfall. Kaunch is anthelmintic, aphrodisiac, astringent, diuretic and nervine tonic. All parts of *Mucuna* posses valuable medicinal properties (Pandey, 1998; 1999) and there is a heavy demand of *Mucuna* in Indian drug markets. After the discovery that *Mucuna* seeds contain L-dopa, an anti-Parkinson's disease drug, its demand in international market has increased many fold (Farooqi, 1999). Seed also contain alkaloids mucuadine, mucunadinine and prurienidine along with mucunin, mucunadine and small amount of nicotine. Its increasing demand has motivated Indian farmers to start commercial cultivation. The itching bean *Mucuna pruriens* (L.) DC var. pruriens is an underutilized legume species grown predominantly in Asia, Africa, in parts of America (Vadivel and Janardhanan, 2000). Velvet bean (*Mucuna pruriens* (L.) is a tropical legume, grown generally for green manure increases the yield of its companion graminaceous crops and smothers the growth of harmful weeds such as nutsedge (*Cyperus* spp.) and alang-alang (*Imperata cylindrica*).It is useful as covers crop and grown for its pods, young leaves, which are used as vegetable and as fodder. Aspect generally refers to the direction towards which a mountain slope faces. The aspect of a mountainous slope can make very significant influence on the growth of a plant species. This can have major effects on the growth and yield attributes of plant species whether light demanding or shade loving. Tillage is any operation or practice taken to prepare the soil surface for the purpose of crop production (Antapa and Angen, 1990) and aims to create a soil environment favourable to plant growth (Klute, 1982). Minimum tillage (also known as reduced tillage or conservation tillage) is a tillage system which creates a suitable environment for growing a crop and leaving a protective cover of residue on and near the soil surface all year round. Farmers get advantage through less labour and more effective erosion control, organic carbon buildup besides saving in time. *Mucuna* is occasionally cultivated and almost plants are collected either legally or illegally all over the Himalayas. The loss or degradation of forest land worldwide has led to the shrinking of habitat thus resulting in depleting medicinal plant. Additionally, there is a need for cultivation of medicinal and aromatic plant on the available waste land, or regenerating in open forest land or using them as green manure crop in the farmer land. However the most important factor for its cultivation is that, it should be cost effective specially on productive areas hence to raise *Mucuna pruriens* in wastelands or in open forest in the mountainous area, here an attempt has been made to determine the impact of aspect and tillage practice on growth and yield attributes of *Mucuna pruriens* in Western Himalayas.

The investigations were carried out at different aspects in, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni Solan, Himachal Pradesh. The experimental site is located within 30° 51' N latitude and 76° 11' E longitude (Survey of India Toposheet No. 55 F/1) at an elevation of 1250 m above mean sea level. The climate of the area is transitional between subtropical to sub-temperate with maximum temperatures rising upto 37.8°C during summer. The mean annual temperature is 19.8°C. In general May and June are the hottest months whereas December and January are the coldest ones. The annual rain fall ranges between 800-1300 mm (75 per cent is received during mid June to mid September). Growth and yield of *Mucuna pruriens* on different aspects and under different tillage practices. *Mucuna* was grown on three aspects viz Northern

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(A1), North western (A2) and Western (A3) at a spacing of 30 cm x 30 cm, followed by three tillage depths viz minimum (T1: 0 cm), Medium (T2: up to 10 cm) and deep tillage (T3 : up to 15 cm). Thus, all possible combination of three aspects and three tillage depths were used for the evaluation of *Mucuna pruriens* performance under three replicates in randomized block design.

The whole experiment was conducted under rainfed conditions entirely dependent on the monsoon rains. Keeping in view the waste land conditions and open forest conditions no irrigation and fertilizer was applied and the selection of *Mucuna* as medicinal plant was done on the basis of its minimum input requirement for irrigation and fertilizers. Prior the commencement of monsoon, seeds were sown at proper spacing after ensuring the sufficient moisture availability in the soil in first fortnight of July, healthy seedlings of *Mucuna* emerged in the experimental field. The crop was harvested in the month of December. The observations on growth parametrers (vine length, leaf area and leaf area index) were recorded at vegetative, pre-bloom and harvesting stage whereas, the data for the yield and the yield attributes were measured at the time of harvesting.

The entire data generated from the present investigation were analysed statistically using the technique of analysis of variance for factorial randomized design in accordance with the procedure outlined by Gomez and Gomez (1984).

The pooled data pertaining to growth and yield character is presented in tables 1 and 2. The perusal of data (Table 1) shows that the vine length, leaf area and leaf area index at harvesting stage was significantly influenced by topographical aspects and tillage practices. At harvesting stage the vine length, leaf area and leaf area index was maximum on western aspect and deep tillage and minimum on northern aspect and minimum tillage respectively. The yield parameters also followed the same trend.

The maximum (1.37 t.ha^{-1}) of seed yield was recorded on western aspect at deep tillage and minimum, (1.35 t.ha^{-1}) on northern aspect at minimum tillage. Similar trend was found with respect to above ground biomass and below ground biomass on different aspects and under different tillage practices (table 2).

Thus in case of Kaunch maximum reduction in the growth and yield attributes was recorded on the northeren aspect. The reason for the reduction in growth and yield attributes of medicinal crop on northern aspect might be due to the fact that northern aspect remained under shade for larger part of the day through the crop season due to which the crop starved of light resulting in poor number of branches per plants, low above ground and below ground dry weight. Moreover, the shade increased in morning and evening hours. Also the intensity of light was significantly reduced under northern aspect. *Mucuna* grows better in warm humid climates, with annual precipitation from 3.8 to 31.5 dm and temperatures between 18.7 and 30 °C; night temperatures of 21 °C promote flowering. The plants are sensitive to frost during the growth season, drought tolerant once established but do not tolerate excess moisture. They grow on various soil types, with pH between 4.5 and 7.7

Table 1. Effect of aspect on different parameters of *Mucuna pruriens*

Aspect	Vine length (m)	Leaf area (cm²)	Leaf area index (LAI)	Above ground dry weight (t.ha^{-1})	Below ground dry weight (t.ha^{-1})	Yield (seed) (t.ha^{-1})
	Harvesting stage					
A_1:Northern	3.21	193.70	2.13	9.370	0.175	1.350
A_2:NorthWestern	3.26	195.90	2.14	9.450	0.178	1.360
A_3:Western	3.31	200.10	2.16	9.500	0.182	1.370
$CD_{0.05}$	0.02	0.25	0.003	0.03	0.0002	0.004
SEm±	0.01	0.12	0.002	0.01	0.0001	0.002

Table 2. Effect of tillage practices on different parameters of *Mucuna pruriens*

Tillage	Vine length (m)	Leaf area (cm²)	Leaf area index (LAI)	Above ground dry weight (t.ha^{-1})	Below ground dry weight (t.ha^{-1})	Yield (seed) (t.ha^{-1})
	Harvesting stage					
T_1:Minimum	3.22	195.50	2.13	9.270	0.175	1.340
T_2:Medium	3.26	196.51	2.15	9.470	0.179	1.360
T_3:Deep	3.31	197.60	2.16	9.590	0.181	1.370
$CD_{0.05}$	0.020	0.250	0.003	0.03	0.0002	0.004
SEm±	0.010	0.120	0.002	0.01	0.0001	0.002

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(Duke, 1981; Kay, 1985; Pugalenthi *et al.*, 2005).

In respect to the tillage practices the value of growth and yield attributes of Kaunch, was significantly higher under deep tillage than other tillage practices. This is substantiated by the fact that deep tillage resulted in to most favourable condition for the growth and development of the medicinal crop. The higher soil moisture content, better nutrient availability was found under deep tillage that promoted the crop which ultimately had more supressing effects on weeds. All these favourable condition resulted in better establishment of *M. pruriens* and hence increased the growth and yield. This plant can be grown easily in degraded land or in open forest patches under different aspect and tillage combinations. The plant as reported by Csurhes and Edwards (1998) can grow in a range of habitats and could become naturalised in grasslands, bushland, riverine forest and forest edges throughout tropical and subtropical regions.

Mucuna pruriens can be cultivated on marginal or degraded land with a sustainable technique using appropriate aspect and tillage practice in the western Himalayas to make its production more cost effective. Because of its legume nature, it can also be grown as green manure in the field to increase the yield of its companion crops.

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Indian Journal of Ecology

Effect of Different Sowing Dates on the Incidence of Aphid, *Hyadaphis coriandari* (Das) on Coriander

Jugal Kishor Bana and H.L. Deshwal

Department of Agricultural Zoology & Entomology
College of Agriculture, Bikaner-334 006, Rajasthan, India
E-mail: jugalbana@gmail.com

Insect-pests are one of the major limiting factors for higher production of good quality coriander leaves as well as seeds. Among the insect-pests of coriander, aphid, *Hyadaphis coriandari* (Das) was reported as major pest in Rajasthan and other parts of country . In Rajasthan, it attacks fennel and coriander crops regularly and causes yield losses upto 50 per cent (Kanwat, 1988 and Lekha, 2002). It is well established fact that attack of insect pests depends upon climatic conditions, crop growth stage and incidence of natural enemies at a particular time. Hence, alterations in sowing time cause a significant effect on the infestation of a specific pest on a given crop. Earlier this practice was evaluated by Lekha (2002), Meena *et al.* (2002) and Kumari and Yadav (2004) on coriander and other workers on different crops, but the climatic conditions have changed now and their effects on pests need reconsideration.

The experiment was conducted in randomized block design at Agronomy farm, College of Agriculture, Bikaner with four treatments (sowing dates) each replicated four times. The plot size was 2.40 x 3 m² with row to row and plant to plant distance of 30 and 10 cm, respectively. The observations on aphid population were recorded soon after the appearance of pest at weekly interval from five plants (three umbels i.e. lower, middle and upper) randomly selected and tagged in each plot till the harvesting of the crop. The correlation coefficient (r) between date of sowing and aphid population; date of sowing and yield; aphid population and yield were also determined by subjecting the data to simple correlation coefficient (r).

The minimum incidence (161.50 aphids per five plants) during peak period was recorded from the crop sown on 15th October, followed by 30th October and 15th November. However, maximum infestation (474 aphids per five plants) was recorded in late sown crop *i.e.* 30th November. It was concluded that the aphid population increased with the delay in sowing time. Highest seed yield (9.32 q ha^{-1}) was obtained from the crop sown on 30th October. The yield in 15th October sown crop was low probably due to early sowing, but was higher than the crop sown on 15th and 30th November. The reduction in yield on late sown crop was probably due to heavy incidence of aphid. The present results are in conformity with that of Jain and Yadav (1989) who reported that sowing beyond 25th November led to an

Table 1. Effect of sowing dates on the incidence of aphid, *H. coriandari* on coriander

Date of sowing	Number of aphids/ five plants		Seed Yield (q ha^{-1})
	Peak	Mean	
15th October, 2006	161.50**(2.21)	49.00(1.69)	8.64
30th October, 2006	182.00(2.26)	60.64(1.78)	9.32
15th November, 2006	306.00(2.47)	109.46(2.04)	7.75
30th November, 2006	474.00(2.67)	168.89(2.23)	5.94
CD (p=0.05)	(0.13)	(0.10)	1.26

*Figures in parenthesis are log x values

Table 2. Correlation between sowing dates, aphid population and seed yield of coriander

Parameters	Correlation coefficients (r)
Sowing dates and aphid population	0.966*
Sowing dates and seed yield	-0.852
Aphid population and seed yield	-0.959*

*Significant at 5% level of significance

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increase in the aphid infestation and reduced yield. Similarly, Lekha (2002) reported that infestation of *H. coriandari* on coriander was more on the crop sown on 20th November as compared to the crop sown on 10th and 20th October.

A significant positive correlation (r=0.966) was obtained between sowing dates and aphid population (Table 2). However, a negative correlation (r = -0.853) existed between sowing dates and seed yield (r = -0.853) and aphid population and seed yield (r= -0.959). Kumari and Yadav (2004) also found highly significant and positive correlation between sowing dates and aphid population on all the tested genotypes of coriander and thus support the present findings.

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Influence of Sowing Dates on Performance of *Bt* Cotton Hybrids (*Gossypium hirsutum* L.)

Sukhbir Singh, H.S. Bajwa and K.S. Saini*

Department of Agronomy, Punjab Agricultural University, Ludhiana
**E-mail: sssaini8@gmail.com*

Cotton, the king of fibres, is an industrial commodity of world wide importance. It is also known as "White gold" because of its importance in national and international economy. It is the backbone of textile industry in India and provides about 85 percent of the raw material to almost 1,000 textile mills and also provides employment to 70 million people in the country. It is an important cash *kharif* crop in Punjab and plays an important role in the agrarian economy of the state, particularly the south west districts. In Punjab cotton occupied an area of 588 thousand hectares with production of 20 lakh bales and an average yield of 736 kg lint ha^{-1} (Anonymous, 2008). About 90 per cent area of total cotton acreage of the state is under American cotton. The productivity of cotton largely depends upon the availability of high yielding varieties and hybrids along with improved agronomic production technology. Among various agronomic factors, sowing time is the most important factor influencing growth and yield of cotton as it influences the duration of vegetative and reproductive period of the crop. Early sown crop attains excessive vegetative growth and has detrimental effect on fruiting behaviour of the crop, whereas late sown crop flowers late and results in boll development in cooler weather resulting in reduced seed cotton yield. In Punjab sowing of cotton is mainly depends on canal water as the ground water is not fit for irrigation, due to this reason the sowing of cotton is extended from end of April to mid of May (Singh *et al.*, 2002). The recommended sowing time of cotton in Punjab is from April to mid May, but due to delayed harvesting and threshing of wheat the farmers are not able to complete their sowing during this period and cotton sowing in south-western region of Punjab continues till end May. Under such conditions the *Bt* cotton hybrids are more promising as these are comparatively fast growing and give better yield even under late sown conditions. Keeping this in view the study was conducted to see the influence of sowing dates on growth and yield of *Bt* cotton hybrids that might help the farmers in selection of hybrids according to the sowing plan.

A field experiment was conducted at Student's Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana, during *Kharif* 2009, to study the growth and yield of *Bt* cotton hybrids (*Gossypium hirsutum* L.) as influenced by different sowing dates. The soil of the experimental field was loamy sand in texture, with normal pH (7.3-7.8) and EC (0.19-0.25 dsm^{-1}). It was low in organic carbon (0.31-0.35 %) and available N (235.3 to 251.7 kg ha^{-1}) and medium in available P (9.5 to 12.1 kg ha^{-1}) and available K (143.2 to 154.1 kg ha^{-1}). The experiment was laid out in split plot design with five sowing dates *viz.* April 20, April 30, May 10, May 20 and May 30, which were kept in main plots and three *Bt* cotton hybrids *i.e.* RCH 134, RCH 314 and MRC 6304,which were kept in sub plots in four replications. All other cultural practices and plant protection measures were given according to the standard recommendations of the Punjab Agricultural University, Ludhiana. The data on plant height, sympods per plant, bolls per pant and boll weight were recorded from randomly selected five plants in each plot and seed cotton yield was recorded on plot basis.

The different sowing dates exerted a significant effect on seed cotton yield which decreased linearly with each shift in sowing date from April 20 to May 30 (Table 1). Among all the sowing dates, April 20 produced highest seed cotton yield, and drastic reduction in yield was noticed after May 10. There was no significant difference in seed cotton yield when sowing was delayed from April 20 to April 30. Although, sowing date May 10 did not give statistically similar yield as April 20, but May 10 can not be considered as poor sowing date because it gave statistically similar yield as April 30. The later sowing dates May 20 and May 30 gave statistically less yield than earlier sowing dates. The reduction in seed cotton yield was recorded when the sowing date was delayed from April 20 to April 30, May 10, May 20 and May 30 was 5.6, 12.0, 30.9 and 40.9 per cent, respectively. The crop sown on later sowing dates was inferior in number of bolls per plant and boll weight and ultimately in seed cotton yield as compared to earlier sowing dates (Table 1). Low yield realization in later sowings was primarily due to shortening of vegetative and reproductive phase. Also in later sowing

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Table 1. Effect of sowing dates on seed cotton yield and yield attributing characters of *Bt* cotton hybrids

Treatments	Plant height (cm)	Sympods/plant (No.)	Bolls/plant (No.)	Boll weight (g)	Seed cotton yield (q/ha)
Date of sowing					
20 April	145.5	25.7	53.8	4.2	24.9
30 April	139.4	24.6	52.2	4.1	23.5
10 May	135.8	22.9	50.1	4.0	21.9
20 May	126.8	20.1	47.1	3.8	17.2
30 May	115.4	18.1	45.1	3.6	14.7
CD (p=0.05)	7.7	2.7	3.5	0.2	2.9
Bt hybrids					
RCH 134	139.0	23.7	53.0	4.0	24.4
RCH 314	123.7	20.1	46.7	3.8	16.5
MRC 6304	135.1	23.0	49.3	3.9	20.6
CD (p=0.05)	6.0	2.2	2.9	NS	2.5
Interaction	NS	NS	NS	NS	NS

NS- Non significant

dates, boll maturation took place under poor environmental conditions, particularly of night temperatures below 18°C, resulting in lower boll weight as compared to the favorable night temperature of 22-24°C during boll development period under earlier sowing dates, thereby, reducing the seed cotton yield in later sowings. The plant height and sympods per plant were also reduced under delayed sowings as compared to earlier sowings due to shortening of vegetative growth period and early commencement of reproductive phase. These results are in conformity with those of Puri (2001), Buttar *et al.* (2004) and Buttar *et al.* (2010) who have also reported high seed cotton yield in early sown crop as compared to late sown crop. The *Bt* cotton hybrids differed significantly in seed cotton yield. The *Bt* cotton hybrid RCH 134 produced significantly higher seed cotton yield (24.4 q ha^{-1}) than MRC 6304 (20.6 q ha^{-1}) and RCH 314 (16.5 q ha^{-1}) (Table 1). The significantly higher seed cotton yield recorded in *Bt* cotton hybrid RCH 134 might be due to more plant height and higher number of sympods per plant, bolls per plant and boll weight (Table 1). The interactions between date of sowing and different *Bt* cotton hybrids were found to be non significant for seed cotton yield, plant height, number of sympods per plant, bolls per plant and boll weight. The results proved the superiority of *Bt* cotton hybrid RCH 134 over MRC 6304 and RCH 314 which can be obtained only by sowing upto April 30.

Thus it was concluded from this study that among the three *Bt* cotton hybrids, RCH 134 is the promising hybrid for farmers under sowing time of second fortnight of April to first fortnight of May.

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Effect of Sulphur and Iron Fertilization on Yield Attribute, Yield and Net Returns of Mungbean [*Vigna radiata* (L.) Wilczeck] in Arid Western Rajasthan

K.K. Meena and R. S. Meena

Department of Agronomy, College of Agriculture
Rajasthan Agricultural University, Bikaner- 334 006, India
E-mail: rsmeenaagro@gmail.com

Mungbean [*Vigna radiata* (L.) Wilczek] is an important source of high quality protein (24.5%). It is the fourth most important grain legumes in India after chickpea, pigeonpea and blackgram. The potential yield level of available improved varieties of mungbean varies between 1200 to 1600 kg ha^{-1}. This indicates a wide gap between the potential yield and average yield being harvested at cultivator's fields. There may be several possible reasons for low yield harvested by the farmers. Lack of optimum mineral nutrition, particularly sulphur and micronutrients management may be one of them. Farmers usually apply nitrogenous and phosphatic fertilizers but sulphur fertilization is lacking in their fertilizer schedule. Further, micronutrients *viz.* zinc and iron deficiencies, now a days are becoming a major limiting factor in harvesting higher yields of crops (Sahu *et al.*, 2007). Pulses not only have high sulphur requirements, but also have the potential to remove sulphur from soil nutrient pool *vis-à-vis* fertilizer applied, as is evident from the radio sulphur investigations (Ganeshamurthy *et al.*, 2005).One of the main reason for the low productivity of greengram is that generally farmers do not apply secondary and micro-nutrients (Ganeshamurthy *et al.*, 2005) Keeping all these factors in mind, the present experiment was conducted at arid Western Rajasthan to study the Effect of sulphur and iron fertilization on productivity of mungbean.

A field experiment was conducted on loamy sand soil at Agronomy Farm, College of Agriculture, SKRAU, Bikaner during *kharif*, 2008. Geographically, Bikaner is situated at 28.01° North latitude and 73.28° East longitudes at an altitude of 234.70 m above MSL. This region falls under agroclimatic zone Ic (Hyper arid partially irrigated north western plain) of Rajasthan. The experiment comprised of four levels of sulphur [control, 40 kg S ha^{-1} as Gypsum, 40 kg S ha^{-1} as elemental sulphur and 40 kg S ha^{-1} as Gypsum + elemental sulphur (1:1)] and four levels of iron [control, 0.5% $FeSO_4$ foliar spray at 25 & 40 DAS, 0.5% $FeSO_4$ + 0.5% citric acid solution spray at 25 & 40 DAS and 25 kg $FeSO_4 ha^{-1}$ as basal application] replicated thrice in randomized complete block design. The gross plot size was 4m x 3 m and net harvested plot area was 3.0 m x 1.8 m. Generally after sowing of the mungbean crop, monsoon rains are received during initial establishment stage only. Thereafter, long dry spell occurs and hence two irrigations at pre flowering and pod filling were applied to the crop for proper growth and development during the growing season. Data on seed yield were recorded from the net plots whereas yield attributes from 5 randomly selected plants at harvest.

Effect of Sulphur

Yield attributes and yield : The number of pods per plant and seeds per pod was significant with 40 kg S ha^{-1} as gypsum and gypsum + elemental sulphur (1:1) source while pod length increased significantly with 40 kg S ha^{-1} irrespective of the sulphur source used as compared to control treatment (Table 1). Application of 40 kg S ha^{-1} as gypsum, and gypsum + elemental sulphur (1:1) registered significantly higher seed yield, straw yield and biological yield and harvest index of mungbean compared to control (Table 1). In element sulphur, higher seed yield, straw yield and biological yield and harvest index were higher than control but lower as compared to gypsum alone or in combination. Similar results were reported by Kumawat *et al.* (2006).

Effect of Iron

Yield attributes and yield : Application of 25 kg $FeSO_4$ ha^{-1} as basal dose and foliar applied treatments *viz.*, 0.5% $FeSO_4$, alone and in combination with 0.1 % citric acid has improved the yield attributes, *viz.*, pod length, number of pods per plant, number of seeds per pod (Table 1). Thus cumulative effects were reflected through increased seed yield. Similar finding have also has been reported by Singh *et al.* (1990). The straw and biological yields also showed similar trend. The beneficial effects of iron nutrition on mungbean, these results are supported by Gupta *et al.* (2002) and Kumawat *et al.* (2006).

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Table 1. Effect of sulphur and iron fertilization on yield attribute, yield and net returns of mungbean

Treatment	Number of pods per plant	Pod length (cm)	Number of seeds per pod	Test weight (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Net returns (₹ ha^{-1})
Sulphur levels and source									
40 kg S ha^{-1} as Gypsum	13.18	7.18	9.14	39.36	1082.81	2281.75	3364.56	32.24	24900
40 kg S ha^{-1} as Elemental sulphur	12.19	7.17	8.86	39.13	1052.27	2304.20	3356.47	31.38	23299
40 kg S ha^{-1} as Gyp+ ES (1:1)	13.18	7.21	9.18	39.11	1107.32	2291.95	3399.27	32.60	25291
Control	11.79	6.77	8.44	38.58	926.03	2170.62	3096.65	29.93	20252
CD (p=0.05)	0.93	0.25	0.33	NS	36.28	97.33	103.34	1.18	1096
Iron levels and source									
0.5% $FeSO_4$	12.80	7.17	8.85	39.41	1058.81	2281.59	3340.40	31.72	24022
foliar spray at									
25 and 40 DAS									
0.5% $FeSO_4$ + 0.1% citric acid foliar spray at 25 and 40 DAS	12.25	7.21	8.55	38.96	1037.73	2235.59	3273.32	31.69	23240
25 kg $FeSO_4$ ha^{-1} basal application	13.57	7.08	9.73	39.13	1081.35	2382.73	3464.08	31.24	24529
Control	11.71	6.88	8.49	38.66	990.53	2148.61	3139.14	31.50	21953
CD (p=0.05)	0.84	0.22	0.30	NS	32.45	87.06	92.43	NS	980

Note: NS= Non-significant; DAS= Days after sowing, ES= Elemental sulphur and Gyp= Gypsum

Net Return

The application of 25 kg $FeSO_4$ ha^{-1} as basal dose being at par with 0.5% $FeSO_4$ foliar sprays at 25 and 40 DAS recorded significantly higher seed yield. The basal application of 25 kg $FeSO_4$ ha^{-1} fetched the maximum net returns of 24529 ₹ ha^{-1} (Table 1).

The present results indicated that application of 40 kg S ha^{-1} as gypsum + elemental sulphur (1:1) and 25 kg $FeSO_4$ ha^{-1} significantly increased the yield attributes; yield and net return were recorded.

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Ecological Perspectives in Pest Management for Sustainable IPM

A.K. Dhawan*, Vijay Kumar and P.S. Shera

Department of Entomology, Punjab Agricultural University, Ludhiana-141 004
**E-mail:ashokdhawan@gmail.com*

Abstract: Ecological basis of pest management (EPM) is an approach to increase the strengths of natural syems to reinformce the natural processes of pest regulatin and improve agricultural production. The mian aim of the EPM is to integrate components so that overall, biological efficiency is improved, biodiversity is preserved and the agroecosystem productivity and its self-sustaining capacty are maintained. EPM provide a balanced environment, sustained yields and natural pest regulation through diversified agroecosystem and use of low input echnologies. The EPM emphasizes the conservation and improvement of soil health and mantenance or incorporation of plant biodiversity in the agroecosystem fr efficient pest management. The major challenge is to identify the correct management techniques and crop assemblages that will provide through their biological synergisms key ecological services such as nutrient cycling, biological pest control, water and soil conservation.

Keywords: Ecological perspectives, pest management, biological control, habitat

In crop protection, chemical control rapidly revealed its limitations, and alternative solutions to pest management problems have been recommended since last six decades. With an increase in public concern over possible adverse health effects of pesticides, more consumers are against the use of pesticides. Initially all consumers, farmers and pesticide applicators were told that organochlorines like DDT, chlordane and dieldrin were safe as long as they were used according to the directions. Later on these chemicals were banned due to their adverse health effects and their inability to break down in the environment. Unfortunately, they were not banned before they killed millions of birds, contaminated soil and water and adversely affected the environment. In fact, DDT is still found in human tissue today. It is well established that insecticides are biological poison and will affect humans and environment if not used judiciously. The scientists have also proven that the use of non target sprays that are applied as a blanket application do more harm than good by creating an imbalance in the ecosystem. The un-judicious use of pesticide led to killing of natural enemies, imbalance in tritrophic interaction and loss of diversity. In the absence of beneficial insects, harmful insect pests flourish unchecked, creating an infestation that is often more severe than the original one and a "need" for another spray to control it. The new strategy was developed under 'Integrated Pest Control', by employment of a range of different control measures, constrained by their compatibility and the requirement for minimizing noxious effects of pesticides on environment. Despite these difficulties, biological, cultural, ecological approach laid the basis of the development of crop protection over the last 50 years. This process has been marked by multiple and diverse interpretations of the concept of IPM (Kogan, 1998). IPM is generally begins by closely monitoring crops and accurately identifying pests and natural enemies. This information then helps to define the appropriate control decisions, including preventative cultural practices such as selecting pest-resistant varieties and rotation between different crops. If monitoring indicates that pest management is needed, a range of options are considered, including mechanical methods such as hand-picking, erecting insect barriers or using sweep nets. If none of these options offer an effective cure, biological insecticides, derived from naturally occurring micro organisms, as well as botanical insecticides can also be used. As a last resort, synthetic pesticides may be considered on an exceptional basis. Numerous technical innovations have been proposed without any significant change in the management of pests in major crops (Lewis *et al.*, 1997) due to an unrealistic approach to the complexities of the phenomena concerned. Basically IPM is described as knowledge intensive approach in farming (Bartett, 2002) with basic block of IPM still regarded as sound knowledge of ecology (Kogan, 1998; Landis *et al.*, 2000; Dufour, 2001; Guerr *et al.*, 2004). The major issues confronting present strategies for insect pest management are:

1. The conventional method of pest management (insecticide based IPM strategies) faces an environmental crisis and sustainability of productivity.

2. The substantial loss of yields due to pests in many crops, despite the increase in the use of pesticides is a symptom of the environmental crisis affecting agriculture. It is well established that crops cultivated in genetically homogeneous monocultures do not possess the necessary ecological defense mechanisms to tolerate the

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fluctuation in agroecosystem which results in outbreak of pest populations and in many situation heavy loss in productivity. In order to feed the growing population, particularly in developing and underdeveloped countries varieties with high yield are selected which are high palatability, making them more susceptible to pests by sacrificing natural resistance against insect pests. On the other hand, modern agricultural practices negatively affect pests' natural enemies, which in turn do not find the necessary environmental resources and opportunities in monocultures to effectively and biologically suppress pests. Thus pest problems will continue to be the result of a negative treadmill that reinforces itself. Thus the major challenge for those advocating ecological pest management (EPM) is to find strategies to overcome the ecological limits impede by monoculture of highly insect pest susceptible varieties.

3. IPM approaches have not addressed the ecological causes of the environmental problems in modern agriculture.

4. Biotechnological approaches do not differ as they are being pursued to address the problems caused by agrochemical based IPM and new concept of bio-revolution is promoted by the same agrochemical industries. Transgenic crops developed for pest control closely follows the paradigm of using single control mechanism. The 'one gene-one pest' approach has proven to be easily overcome by pests that are continuously adapting to new situations and evolving detoxification mechanisms. There are many unanswered ecological questions regarding the impact of the release of transgenic plants. Among the major environmental risks associated with genetically engineered plants are the unintended transfer to plant relatives of the 'transgene' and the unpredictable ecological effects (Rissler and Mellon, 1996). The spectacular success of the recent advances in biotechnology has also raised much issue regarding long term impact on environment.

Due to many socio-economic and ecological reasons, re-examination of farming systems as traditionally practiced, through an innovative agroecological approach need a fresh relook keeping in view the current pest management options which are not sustainable as these are mainly based on pesticides as solution to pest problems in farmers perspectives. Ecological approaches to pest management draw on this knowledge to design and manage ecosystems to (i) make the crop (and habitat) unacceptable and resistant to pests by interfering with their oviposition preferences, host plant discrimination or location by both adults and immature; (ii) make the crop unavailable to the pests in space and time by utilizing knowledge of the pest's life history, especially its dispersal and overwintering habits (iii) reduce pest survival on the crop by supporting its natural enemies, particularly by enhancing predator evenness and by reducing the crop's susceptibility to the pest (Dalgaard *et al.*, 2003). This particularly involves doing things that favour the crop and the natural controls and that discourage and impact on the pests. EPM program which are safe and very effective alternatives to pesticide based IPM should be part of policy decisions for implementation may be by legislative options. However, at present a more holistic approach is necessary for a comprehensive EPM program to be successful.

I. Ecological perspectives and ecosystem management

Ecological basis of pest management is an approach to increasing the strengths of natural systems to reinforce the natural processes of pest regulation and improve agricultural production. Integrated Pest Management (IPM), "defined as the use of multiple tactics in a compatible manner to maintain pest populations at levels below those causing economic injury while providing protection against hazards to humans, animals, plants and the environment. IPM is thus ecologically-based pest management that makes full use of natural and cultural processes and methods, including host resistance and biological control. This approach laid emphasis on the growth of a healthy crop with the least possible disruption of agro-ecosystems, thereby encouraging natural pest control mechanisms. Chemical pesticides are used only where and when these natural methods fail to keep pests below damaging levels. Worldwide public attention has been focused on the importance of ecological approach to pest management (EPM) since the United Nations Conference on Environment and Development held in Rio de Janeiro in June 1992. Agenda 21 and identified IPM as a key element in sustainable agricultural development. Understanding and managing an ecosystem including pest management, should be designed as the pest management practices on one crop can directly or indirectly affect the other. Impact of cropping pattern and associated practices at farm and community levels on insect pest development need to be the basis of sound pest management practices. Many authors have suggested the ecological foundations of IPM (Croft *et al.*, 1984; Rabb *et al.*, 1984; Horn, 1988; Kogan, 1988; Price and Waldbauer, 1994). The ecological information about pests and their crop environment is crucial for sustainable IPM and is also referred as applied ecology/ agroecology. The 'agro-ecosystems management' or 'agro-ecological engineering' is today recognized as one of the upcoming concepts in pest management (Clements and Shrestha, 2004; Gurr *et al.*, 2004; Nicholls and Altieri, 2004).

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Agroecological based pest management combines plant and animal community management and thus contributes to conservation and biological control. By prioritizing preventative measures, the system seeks to establish bioecological equilibrium between animal and plant communities within an agroecosystem with the goal of reducing the risks of infestation or outbreaks of pests. The pest management should be driven by an improved understanding of the functioning of ecosystems. This forms the agroecological approach for the development of a concept of integrated pest management and then of integrated production or integrated crop management. This development laid more stress on evolution of traditional concepts for understanding pest management strategies. The pest management is thus based on ecological processes occurring not only between the crop and its pests (Carroll *et al.*, 1990), but also the natural enemies of these pests (Weiner, 2003), for increased beneficial interactions that keep pest populations in check (Altieri and Nicholls, 1999; Gliessman, 2007). This combines the life cycle of crops, insects and good harvesting even in difficult conditions of pests that emerge with the change in climate. EPM contributes to climate change adaptation by providing a healthy and balanced ecosystem in which the vulnerability of plants to pests. By promoting a diversified farming system, the practice of EPM builds farmers' resilience to potential risks posed by climate change, such as damage to crop yields caused by newly emerging pests.

The EPM emphasizes the conservation and improvement of the "health" of soils (fertility, biological activity, structure, etc.) and the maintenance or incorporation of plant biodiversity in the agroecosystem for efficient pest management. According to these criteria, the use of pesticides may only be for short term. The prophylaxis, habitat management and biological control are the principal components of ecological pest management. Agroecological crop protection operates at larger scales in time and space and thus requires concerted action by stakeholders, notably farmers, scientific community, extension agencies and policy planner.

The principles IPM, developed during the last few decades, have led to new orientations to crop protection which will require a return to utilizing knowledge and skills progressively lost over the last few decades. A major contribution of EPM based IPM to agriculture, is the incorporation of ecological principles into pest management while ensuring high productivity and profitable harvests. Preserving ecosystems and biodiversity, while reducing pesticide use, is a challenge that must now be addressed to ensure that agriculture will be both intensive and environmentally friendly. What is going on outside of the agroecosystem that can be manipulated to prevent or minimize insect pest outbreaks? In many cases, this important question is neglected and long-term pest management can be seriously hampered. Deguine *et al.* (2009) also proposed a five strategy to implement the agroecological crop protection approach:

(a) Grow healthy plants and ensure good soil health utilizing prophylaxis, varietal selection, crop rotations, whole-farm crop planning, cultural practices (such as sowing under plant cover and minimum tillage), management of weeds, rational irrigation and fertilization, use of organic fertilizers.

(b) Reduce pest populations and increase populations of beneficial organisms (at the level of the individual field, its surroundings, of the farm and of the entire agroecosystem): crops or trap crops, planting of refuge areas, plant associations and intercropping, the *push-pull* technique, establishment of field margins, planning of ecological compensation structures (corridors, hedgerows, grassy and flowering strips etc.), techniques designed to incorporate vegetative diversity.

(c) Evaluate the real socio-economic and environmental risks by using pest scouting techniques appropriate for one field, a group of fields, a farm, or the whole ecosystem, with the assistance of the regional agricultural extension services.

(d) Take only need-based decisions on curative measures: (i) With the aid of decision tools and in collaboration with fellow producers, accounting for local and ever changing multiple criteria, intervention thresholds (economic, social, environmental) and of the risk of development of resistance; (ii) In the framework of whole-of-farm management and at a range of time scales (short to long term), account for the agroecological characteristics of the agroecosystem as a whole (the spatial dimension).

(e) Only in the case of absolute necessity, apply curative measures: (i) Give priority to alternative control measures: cultural techniques (e.g. defoliation, plant topping), biological control, physical and biotechnical control measures; (ii) only as a last resort: use the chemical pesticides.

II. Population dynamics

Monitoring pest population: The intensity of pest damage depends on fluctuations in population of insect pests and their natural enemies in response to biotic and abiotic factors. Therefore, it is extremely important to monitor

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the populations so that adequate forecasting may be made and decisions about pest management tactics may be finalized. Monitoring phytophagous insects and their natural enemies is a fundamental tool in IPM for taking management decisions. Monitoring requires estimation of changes in insect distribution and abundance, information about insect's life history and influence of abiotic and biotic factors on pest population. A number of sampling tools have been developed to make inferences regarding the total insect population as based on smaller samples (Binns and Nyrop, 1992; Reusink and Kogen, 1994).

Sampling techniques: The sampling procedures need to be modified to overcome the limitations of sampling key as component of pest management programme (Dhaliwal *et al.*, 1998). Because IPM is a continuous process, temporal changes in insect abundance should be explicitly considered in sampling programmes. Secondly two or more pest species causing the same type of damage may be simultaneously present in the field and make the sampling difficult. Thirdly, few IPM programmes at farmers' level attempt to estimate the abundance and impact of natural enemies on insect populations. There is an urgent need to develop efficient and cost effective procedures and forecasting models which incorporate the role of natural enemies in decision making process. The sophisticated methods for tracking and monitoring populations of pests and biological-control organisms to optimize timing of applications of biological or chemical supplements and to avoid unnecessary risks associated with the application of supra-optimal concentrations of these supplements should be exploited. New site-specific techniques such as geographic information systems (GIS) and remote sensing already are useful in geographic applications and can potentially be useful in tracking and monitoring pest movements. Studies of insect population dynamics in different habitats may also improve the ability to predict insect pest outbreaks and could facilitate the development of sustainable pest control in managed systems.

Climate change and pest population: Insects are likely to be affected by climate change because they are ectodermic and sensitive to precipitation (Bale *et al.*, 2002). Understanding how weather and climate influence insect populations is vital for developing predictive population models. Factors such as temperatures and rainfall patterns can exert strong influences on insect populations and their growth. These populations vary over seasonal and yearly time scales and can sometimes quickly erupt and achieve outbreak status. Therefore, predicting pest outbreaks is vital to preparing growers for potential pest problems before serious losses occur. To elucidate population patterns of a pest insect and their relation to weather and climate requires frequent population sampling over duration of many months and years and within several areas within its range, as well as access to reliable weather records from the same area(s) of the population samples. These effects of climate on pest population can be direct, through the influence of climatic factors on the insects' physiology and behavior (Cannon, 1998; Harrington *et al.*, 2001; Bale *et al.*, 2002; Parmesan, 2007; Merrill *et al.*, 2008), or indirectly mediated by host plants, competitors or natural enemies (Lincoln *et al.*, 1984; Harrington *et al.*, 2001; Bale *et al.*, 2002; Kiritani, 2006; Laštùvka, 2009). These climate change on pest population can cause a shift in geographical spread (Porter *et al.*, 1991; Ward and Masters, 2007), abundance (Ayres and Lombardero, 2000; Olfert and Weiss, 2006) or diversity (Sharon *et al.*, 2001; Conrad *et al.*, 2002; Feehan *et al.*, 2009). It can change the location, the timing and the magnitude of outbreaks of pests (Volney and Fleming, 2000), and can define the phenological or even the genetic properties of the species (Gordo and Sanz, 2006; Parmesan, 2007). Long-time investigations of special insect populations, simulation models and scenario studies give us very important information about the response of the insects far away and near to our century. Getting to know the potential responses of insect populations to climate change makes us possible to evaluate the adaptation of pest management alternatives as well as to formulate our future management policy.

III. Habitat Management

It is very important to understand the role of plants in managing insect populations, as the plant has many attributes which attract or repel insect herbivores and natural enemies (Cortesero *et al.*, 2000; Wackers *et al.*, 2005). The UN Conference on the Environment and Development in Rio de Janeiro in 1992 laid emphasis to preserve the biological diversity of ecosystems in general and agroecosystems in particular. The cropping system approach in IPM is a low input system, which existed in subsistence farming and was of traditional method of pest management before the introduction of pesticides. The habitat diversification / management which has great impact on management of pests as it plays significant role in deterrence of colonization through intra-field diversity, because only a little additional diversity in the crop field may have a profound effect on colonization of insects. Habitat management relies mainly on the enhancing the biodiversity of plants and pest's natural enemies in and around the cropping environment. The diversity of wild host and non-host plants and their associated arthropods in agroecosystem and surrounding areas influences the

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abundance of insect pests and severity of damage. Increasing the diversity within crops provide a greater number of opportunities for natural enemies to survive in agricultural systems. Conventional method with no manipulation of habitat leads to high pest population numbers and few natural enemies entering the crop from the surrounding landscapes. Thus, pest outbreaks tend to be less common in polycultures than in monocultures (Root, 1973; Andow, 1991). Crop diversification also tends to increase natural enemy abundance and diversity, providing a system more resilient to pest population increase. Overall farming diversity within the agroecosystem may also affect biological control by natural enemies. Wider range of flowering plants provides nectar (carbohydrate) and pollen (protein) resources to beneficial insects for longer period during of the growing season. Thus vegetation diversity can provide support for insect biological control (Thies *et al.*, 2003; Roschewitz *et al.*, 2005; Bianchi *et al.*, 2006). Farmers can make some simple changes to their crop systems to manipulate vegetation diversity, through addition of plants that provide specific functions (Landis *et al.*, 2000; Gurr *et al.*, 2003; Isaacs *et al.*, 2009). Intercropping, trap cropping, presence of weeds can increase the diversity of a crop system by crops grown in the field adjacent to fields. When interplanted or weeds in the crop are also suitable hosts plants for a particular pest, they may reduce the feeding damage to the main crop by diverting the pests. On the other hand, these may also serve as an essential source of food or shelter at some point in the life cycle or during some part of season, enabling the pest to maintain or build up its number in the field and also to attack the main crop more severely. The existing habitat structure therefore should be designed considering the complex system of the biodiversity of the host plants, pests/ pathogens/ weeds, their natural enemies and their interaction. Sustainable systems of agricultural production are seen in areas where proper mixes of crops and varieties are adopted in a given agroecosystem. Monocultures and overlapping crop seasons are more prone to severe outbreak of pests and diseases. One of the reasons for adoption of mixed cropping in marginal farming and in rainfed ecosystem is due to the low incidence of pests which was due to the increased activity of natural enemies. The diversity of natural enemies that attack pests at various stages of the life cycle is greater in poly crop systems, which also tends to prevent severe pest outbreaks. The cropping system approach proliferates natural enemies by providing food and shelter and prevents the evacuation of these biological control agents from the agroecosystem by biological (host plant, prey density) and physical (protection from wind, hiding, shading) interference mechanisms. Therefore, crop diversity should be manipulated to the disadvantage of the pest. The conservation of natural enemies by direct enhancement of vegetation diversity has been the subject of study for many years (Andow, 1991). The addition of inter-cropping, cover crops, or supplemental food sources to an agroecosystem may lead to an increase in natural enemy abundance and a potential decrease in insect pest abundance within field settings, but relies on the presence of insect pests to attract natural enemies into the crop. The addition of semiochemical-based lures, such as herbivore-induced plant volatiles (HIPVs) may attract natural enemies into the crop to enhance biological control, but does not provide resources to directly enhance natural enemy abundance. Combining habitat manipulation and HIPV strategies in an agroecosystem may increase natural enemy abundance within field settings as well as directly attract natural enemies into the crop to enhance biological control. The work conducted in Kenya has shown that the abundance and species composition of wild graminaceous plants growing in the proximity of maize fields influences the density of lepidopteron stem borers and their natural enemies (Khan, 1998). Similarly, by improving the availability of food, shelter and other environmental resources in and outside the crop field, there are possibilities of increasing the populations of effective predator and parasitoid. In general, in polycultural agroecosystems there is great abundance of arthropod predators and parasitoids due to enhanced availability of alternate prey, nectar sources and suitable microhabitats.

IV. Host Plant Resistance

Host plant resistance (HPR) is regarded as another basic requisite for pest management. There are many varieties developed which are resistant to pests. Plants have long been known to possess toxins and other chemicals that discourage herbivore feeding. Host-plant resistance directed toward breeding plants resistant to pest attack was developed around such knowledge and contributed greatly to pest management. The plants play an active and sophisticated role in their defense against insect activities and their defense responses often are customized for certain, interactive, multitrophic situations (Altieri, 1995). Plant genotype strongly influences the abundance, distribution and fitness of herbivores on a plant and the amount of damage that results from injury by herbivores to the plant (Marquis, 1992; Peterson and Higley, 2001; Hochwender *et al.*, 2005). Moreover, significant variation in genetically based resistance exists within most crop plant species (Kennedy and Barbour, 1992; Clement

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and Quisenberry, 1999, Dhawan, 2001, 2004). Host-plant resistance as a management tool involves the exploitation of intra-specific variation in genetically based plant resistance to breed crop varieties that support lower populations of herbivores or tolerate injury by herbivores and the integration of said varieties with other management tactics such as insecticide applications and biological control. Traits conferring host plant resistance to insects are the most important for crop improvement. Insect resistance has also been introduced into several hundred-crop varieties during the last 50 years. Globally more than 400 breeding programs in 100 countries have released more than 8000 varieties of 15 major crops and its importance is increasing as insecticides lose efficacy due to pest adaptation or are removed from use to protect the environment and human health (Eigenbrode *et al.*, 1994). Resistant cultivars of wheat and rice to pest have played a significant role in management of pests on these crops. Often, successful crop production is impossible without resistance to insects that otherwise cannot be economically controlled. In many cases, multiple genes are required for sustained resistance to counter pest adaptation. Thus, maintaining agricultural productivity to meet world food needs depends on access by agricultural scientists to plentiful sources of HPR genes. There are several other barriers to the increased development and use of resistant cultivars in IPM. Many of these barriers arise from the complex genetic and phenotypic nature of plant resistance. Three keys to overcoming these barriers are: increased understanding of the causal bases of plant resistance, increased application of modern genetic tools and a more quantitative approach to implementing host plant resistance. Another major limitation is development of cultivars which are resistant to pests and also have with good agronomic characters. There are many constraints in identifying the source of resistance and transfer to varieties with most competitive traits. For example, some plants respond to insect herbivory by releasing volatile chemical cues that attract predators and parasitoids that, in turn, attack the herbivores (Price *et al.*, 1980; Dicke *et al.*, 1990). These volatiles are released only in response to herbivore damage, not by mechanical damage similar to herbivory and are released from the entire plant. Host plant resistance has been found to be compatible with natural enemies but secondary plant compounds in some cases may affect the natural enemies. In similar way, use of insecticides has been reduced considerably on insect resistance, but sometimes, secondary plants compounds lead to incompatibility of insecticides with resistance plants. These compounds increase the activity of detoxifying enzymes which enable the plants to tolerate insecticide.

V. Tritrophic Interactions

Recent discoveries of tritrophic level interactions among plants, herbivores and parasitoids/predators have demonstrated how tightly interwoven these components are and illustrate the importance of multitrophic perspectives for effective and sustainable pest management strategies. Pest management entails the manipulation of plant-herbivore-natural enemy interactions with the goal of regulating populations of the herbivore at levels below those at which economic losses occur. The physical, morphological, physiological and cultural characters of plants interact with the parasitoids and predators of insects by influencing their host seeking ability and affecting the efficacy by which they locate and utilize hosts. The pest management utilizes the knowledge of crop, pests and naturally occurring beneficial organisms in such a way that reduces the pest damage. The external input must target specific pests with least disturbance to copping ecosystem. The organisms in ecosystem interact in many ways-through competition, host selection, predation, antibiosis, etc. Understanding these interactions can help in understanding the new pest problems and devising strategies to manage them. The resistant variety facilitates searching behaviour of the natural enemies, reduces the vigor of the host insect to avoid parasitization, delays the development of the host insect so that pest and natural enemies populations are synchronized and also modifies the behaviour of the host insect so that it is more easily attacked. This traditional method of farming practice needs a modern touch in view of plant-host-natural enemy relationship.

VI. Biological Control

Modern concept of IPM laid stress on development of biological-control organisms that can be used to reproduce natural processes of pest suppression. Identification of biological-control organisms is leading to commercialized products that can effectively suppress specific pests with increased safety to human health and the environment. Biological control has a long history of significant role in pest management and has gained importance as key components of IPM because of problems encountered with the use of pesticides and has been spectacularly successful in many instances, with a number of pest problems permanently resolved by importation and successful establishment of natural enemies. These importation successes have been limited largely to certain types of ecosystems and/or pest situations such as introduced pests in perennial ecosystems. On the other hand, this approach has met with limited success for major

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pests of row crops or other ephemeral systems. In these situations, the problem is often not the lack of effective natural enemies but management practices and a lack of concerted research on factors that determine the success or failure of importation attempts in the specific agroecosystem setting. Thus, importation programs, to date, are largely a matter of trial and error based on experience of the individual specialists involved. This includes full spectrum of biological organisms and biologically based products. In keeping with the historical therapeutic-based attitude and existing infrastructure, most concentrated efforts for biological control appear to be directed toward the "rear and release" augmentation, followed by importation and thirdly by conservation. First, we need to understand, promote and maximize the effectiveness of indigenous populations of natural enemies.

Conservation of natural enemies received more attention as part of a cultural management approach before the advent of synthetic pesticides. Since that time, this realm of biological control has been neglected. The term "conservation" tends to limit one's vision to a passive approach of acknowledging that natural enemies are valuable and should be harmed no more than necessary. It is important to develop a more active approach that seeks to understand natural enemies and how they function as a part of the ecosystem and to promote their effectiveness by use of habitat management (landscape ecology) and other cultural management approaches. Although the importation of new natural enemies is important to farmers, the scope of successful introduction (involving considerable expertise, foreign exploration, quarantine, mass rearing and establishment) can only initiated by government agencies. Another important concern is conserving natural enemies which are the most important factor in increasing the impact of biological control on pest populations. This is important because a great number of beneficial species exist naturally and help to regulate pest densities. The practices that conserve the natural enemies, favors the increase in populations of natural enemies and result in minimizing insecticide applications.

Augmentation through propagation and release of natural enemies is an area of biological control that has received much attention in recent years. These efforts include research on *in vitro* and *in vivo* mass rearing technology and on transport and release methodology for area-wide population suppression and for field-to-field therapeutic treatments. In principle, natural enemies used in these methodologies are biopesticides and the general approaches differ from conventional pesticidal applications only in the kind of products used. From this "product formulation" perspective and from our existing infrastructure, the major emphasis in augmentation becomes focused on how to produce and transport a large number of natural enemies at a low cost. Less emphasis is placed on how natural enemies function and how to promote their natural effectiveness. The releasing natural enemies into areas where they are absent or exist at densities too low can provide effective levels of biological control (augmentation). In addition, conservation and augmentation may be used together in a variety of ways to produce the best results.

Beyond the classical techniques of integrated crop protection, emphasis is placed on cultural practices and plant management systems which help maintain or create habitats to attract indigenous beneficial fauna and/or repel pest fauna. Biological control of pest species has traditionally focused on specific natural enemies for each pest (van Lenteren and Woets, 1988; Hoy, 1994). However, pest-enemy interactions are often embedded in rich communities of multiple interacting pests and natural enemies and the interactions among these species affect the efficacy of biological pest control (Janssen *et al.*, 1998; Prasad and Snyder, 2006; Evans, 2008). Much has been learned from prior releases of biological control organisms and this information can provide a basis for assessment of future risks associated with the use of biological control organisms in agriculture. Biological control has a credible history for management of insect pests in agriculture. The negative effects on non-target organisms have been observed in very few cases. If a biological control organism is unfamiliar or there is uncertainty about the environment into which it is introduced, the careful evaluation must precede its introduction. Non-target organisms closely related to the pest are most at risk from parasitism or predation by introduced natural enemies, although quantification of such risk requires more evaluation. There is also a small possibility of exacerbating pest problems following introduction of biological-control organisms. Unknown consequences of genetic exchange between biological-control agents and indigenous organisms also may exist, but field evaluation can assess the likelihood effects of these events in a natural setting.

The effect of interactions among various species of predators and parasitoids on biological control of a shared pest species has received ample and it can range from larger to smaller than the effect of each enemy species separately (Rosenheim *et al.*, 1995; Rosenheim, 1998; Losey and Denno, 1998; Colfer and Rosenheim, 2001; Venzon *et al.*, 2001; Cardinale *et al.*, 2003; Snyder and Ives, 2001; Finke and Denno, 2004; Cakmak *et al.*, 2009). However, it is not only predator diversity, but also the diversity

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of herbivorous prey that may affect the suppression of a particular pest species through competition or indirect interactions mediated by host plant or shared predators (Karban and Carey, 1984). Hence, designing effective biological control programs for more than one pest species requires an understanding of all interactions occurring among species within biocontrol communities, not just those among pests and their natural enemies or among different species of natural enemies. Plants are not capable of running away from their enemies, but under certain circumstances, plants can rely on the natural enemies of insect herbivores for protection. These natural enemies include other insects that are predators and parasitoids. To help protect plants from damage caused by insect herbivores, practical methods have been developed and evaluated to conserve and augment natural enemies of several agricultural pests. These strategies include improving the suitability of the crop landscape for natural enemies by manipulating the resources available for these insects and the use of semiochemical to attract predators and parasitoids.

Most insecticides kill predators and parasitoids along with pests. In many instances natural enemies are more susceptible than pests to commonly used insecticides. Using selective insecticides or using insecticides in a selective manner, leaving certain areas unsprayed or altering application methods can also favor survival of beneficial. Maintaining ground covers, standing crops, and crop residues provide protection for overwinter and survival.

VII Transgenic Crops

Genetic engineering and other such technologies are powerful tools of great value in pest management. But, if their deployment is to be sustainable, they must be used in conjunction with a solid appreciation of multitrophic interactions and in ways that anticipate countermoves within the systems. Otherwise, their effectiveness is prone to neutralization by resistance in the same manner as with pesticides. Plant biodiversity is the most important consideration when dispersing the benefits of resource poor farmers using transgenic crops in developing countries. These resource poor farmers have profound knowledge of biodiversity. This knowledge and environment perceptions must be integrated in evolving strategies for under developed and developing countries. The introduction of transgenic crops may lead to reduction in genetic diversity of traditional crop varieties and development of transgene resistant pest population with little or no gain to poor farmers. The transgenic crops may be suitable for big agriculture business countries and relatively low diversity of plant species. Genetically engineered (GE) crops have been developed in corn, cotton and potatoes for control of European corn borer (ECB), bollworms and Colorado potato beetle, respectively (WWF, 2000). Bt corn is the most extensively planted crop and it is claimed that this will provide better ECB control with significantly lower insecticide applications. However, as ECB is usually only a significant pest problem every year the field corn is not sprayed most of the years. Unless ECB pressures are high, GE varieties were more costly to use under conditions of low to moderate ECB infestations. Only high ECB pressures would make the GE varieties profitable. Furthermore, conventionally bred (non-GE) corn borer resistant hybrids perform well under low to moderate corn borer infestations.

VIII. New Era of Pest Management

Much has been discussed about EPM and it is time to put it in practice and public oversight of EPM should be addressed. During last two decades experimentation has been done and it is time for dissemination and area specific validation of EPM. There is no alternative to EPM as :

- EPM provides the guidelines to carefully manage agroecosystem without irreparable damage. In agroecology, biodiversification is the primary technique to evoke self regulation and sustainability.
- From a management perspective, the EPM objective is to provide a balanced environment, sustained yields and natural pest regulation through the design of diversified agroecosystem and the use of low-input technologies. The strategy is based on ecological principles that lead management to optimal recycling nutrients and organic matter turnover, closed energy flows, water and soil conservation and balanced pest-natural enemy populations.
- Ecological concepts are utilized to favor natural processes and biological interactions that optimize synergies so that diversified farms are able to sponsor their own soil fertility, crop protection and productivity.
- EPM takes greater advantage of natural processes and beneficial on farm interactions in order to reduce off-farm input use and to improve the efficiency of farming systems. Technologies emphasized tend to enhance the functional biodiversity of agroecosystem as well as the conservation of existing on-farm resources. Promoted technologies are multi-functional as their adoption usually means favorable changes in various components of the farming systems at the same time.
- The ultimate goal of EPM is to integrate components so that overall biological efficiency is improved, biodiversity is preserved, and the agroecosystem

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productivity and its self-sustaining capacity are maintained. The goal is to design an agroecosystem that mimics the structure and function of natural ecosystem, that is systems that include:

- Pest regulation assured through enhanced activity of biological control agents achieved by introducing and/or conserving natural enemies.
- The process of conversion from a high-input conventional management to a low-external input management is a transitional process with four marked phases:
  - Progressive withdrawal of toxic insecticide/ replacement with green pesticides.
  - Rationalization the efficiency of agrochemical use through integrated pest management (IPM) and integrated nutrient management.
  - Input substitution, using alternative, low-energy input technologies.
  - Integration which encourages synergisms so that the system can sponsor its own soil fertility, natural pest regulation, and crop productivity.

The challenge for EPM scientists is to identify the correct management techniques and crop assemblages that will provide through their biological synergisms key ecological services such as nutrient cycling, biological pest control, and water and soil conservation.

IX. CONCLUSIONS

The complexity of managed ecosystems necessitates coordinated multidisciplinary and interdisciplinary research to develop and implement EPM. The knowledge needed to build the foundation of EPM will come from nearly all disciplines and will require research from molecular to landscape levels. It is necessary to refocus objectives from pest control to pest management based on maintaining natural ecological balances and must address the problems of consumer and societal acceptance, safety, pest resistance, and economic cost. There needs to be a paradigm shift in pest-management theory from managing components or individual organisms to an approach that examines processes, flows, and relationships among organisms. There is an opportunity to move beyond IPM and into an information-rich era in which collaborative efforts break down current barriers among the disciplines, institutions, and philosophies to achieve ecologically based pest-management solutions that are safe, profitable, and durable. The principles of EBPM are essential to sustainability of agricultural production systems and its implementation is essential for profitable production of a safe and wholesome food supply while minimizing hazards of environmental pollution that could threaten entire ecosystems. To make the transition from chemically based to ecologically based pest management strategies, production and processing systems must be aggressive in developing the human and information resources required. To further strengthened EPM , the broad research areas that should receive priority in EPM are:

- Ecological research of managed ecosystems, and to devise new methods to study, monitor, and evaluate agricultural ecosystem processes and to develop effective pest-management tools
- Research of behavioral, physiological, and molecular mechanisms affecting EBPM
- Identification and conservation of resources necessary for EBPM, development of better research and diagnostic techniques
- Development of ecologically based crop protection strategies
- Research on socioeconomic issues and implementation of EBPM.
- Development of new institutional approaches to encourage interdisciplinary cooperation.

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Climate Change: Impact on Insect Pests and their Management

Ram Singh[1], Vikas Jindal[2] and G.S. Dhaliwal[3*]

[1]*CCS Haryana Agricultural University, Hisar, 125004, India*
[2]*Department of Entomology, Punjab Agricultural University, Ludhiana, 141004, India*
[3]*Insect Biopesticide Research Centre, Jalandhar, 144003, India*
**E-mail: gurmail_d@yahoo.in*

Abstract: Climate change will have serious consequences on diversity and abundance of insect pests and extent of losses. Pest outbreaks might occur more frequently, particularly during extended periods of drought, followed by heavy rainfall. Some of the components of pest management such as host plant resistance, microbial biopesticides and natural enemies will be rendered less effective as a result of increase in temperatures and UV radiation, and decrease in relative humidity. Adverse effects of climate change on the activity and effectiveness of natural enemies will be a major concern in future pest management programmes.

Key Words: Climate change, temperatures, CO_2, insect pests, pest management strategies.

Food plants of the world are damaged by more than 10,000 species of insects, 30,000 species of weeds, 100,000 diseases (caused by fungi, viruses, bacteria and other microorganisms) and 1000 species of nematodes, and cause an estimated annual loss of 13.6 per cent globally and 23.3 per cent in India (Dhaliwal *et al.*, 2007). Indian agriculture suffers annual losses to the tune of Rs 900 billion due to the ravages of arthropod pests in field and diseases of storage (Dhaliwal *et al.,* 2013). Losses due to insect damage are likely to increase as a result of changes in crop diversity and increased incidence of insect pests due to global warming. Current estimates of changes in climate indicate an increase in global mean annual temperature of 1°C by 2025, and 3°C by the end of the next century. The date at which an equivalent doubling of CO_2 will be attained is estimated to be between 2025 and 2070, depending on the level of emission of greenhouse gasses (IPCC 1990 a,b).

Insect Biodiversity and Extinction of Species

Biodiversity plays an important role in abundance of insect pests and their natural enemies. Changes in cropping pattern as a result of climate change will drastically affect the balance between insect pests and their natural enemies. Since climate change will lead to a shift in cultivation of crops in non-traditional areas and crop rotations, this may influence the prevalence and importance of specific pests. Main effects of climate change and pollution on insect communities result in decreased abundance of decomposers and predators, and increased herbivory, which may have negative consequences for structure and services of the entire ecosystems. Speciation takes between 100 and 1,000,000 years, providing between 10 and 10,000 new species per annum. Nearly 99.9 per cent of all species that ever existed have become extinct. We are now living through the sixth extinction spasm, which is largely driven by human activities. The relative abundance of different insect species may change rapidly due to climate change, and the species unable to withstand the stresses may be lost in the near future. The current extinction rates are 100 to 1,000 times greater than what has happened earlier, and nearly 45 to 275 species are becoming extinct everyday.

Geographical Distribution of Insects

Climate change will have major effect on geographical distribution of many insect pests, and low temperatures are often more important than high temperatures in determining geographical distribution of insect pests. Increasing temperatures may result in a greater ability to overwinter in insect species limited by low temperatures at higher latitudes, extending their geographical range and sudden outbreaks of insect pests can wipe out certain crop species, and also encourage the invasion by exotic species. Spatial shifts in distribution of crops under changing climatic conditions will also influence the distribution of insect pests in a geographical region. Some plant species may be unable to follow the climate change, resulting in extinction of species that are specific to particular hosts. However, whether or not an insect pest would move with a crop into a new habitat will depend on other environmental conditions such as the presence of overwintering sites, soil type, and moisture, e.g. populations of the corn earworm, *Helicoverpa zea* (Boddie) in the North America might move to higher latitudes/altitudes, leading to greater damage in maize and other crops. For all the insect species, higher temperatures, below the species upper threshold limit, will result in faster development and rapid increase in pest populations as the

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time to reproductive maturity will be reduced considerably.

In addition to the direct effects of temperature changes on development rates, improvement in food quality due to abiotic stress may result in dramatic increases in growth of some insect species, while the growth of certain insect pests may be adversely affected (Maffei *et al.*, 2007). Pest outbreaks are more likely to occur with stressed plants as a result of weakening of plants' defensive system, and thus, increasing the level of susceptibility to insect pests (Rhoades, 1985).

Global warming will lead to earlier infestation by *H. zea* in North America, and *Helicoverpa armigera* (Hubner) in North India, resulting in increased crop loss. Rising temperatures are likely to result in availability of new niches for insect pests. Temperature has a strong influence on the viability and incubation period of *H. armigera* eggs. Egg incubation period can be predicted based on day degrees required for egg hatching, which decreases with an increase in temperature from 10 to 27 °C, and egg age from 0 to 3 days (Dhillon and Sharma, 2007). An increase of 3°C in mean daily temperature would cause the carrot fly, *Delia radicum* (Linnaeus) to become active a month earlier than at present, and temperature increases of 5 to 10°C would result in completion of four generations each year, necessitating adoption of new pest control strategies (Collier *et al.*, 1991). An increase of 2°C will reduce the generation turnover of the bird cherry aphid, *Rhopalosiphum padi* (Linnaeus) by varying levels, depending on the changes in mean temperature. An increase of 1° to 3°C in temperature will cause northward shifts in the potential distribution of the European corn borer, *Ostrinia nubilalis* (Hubner) up to 1,220 km, with an additional generation in nearly all regions where it is currently known to occur (Sharma, 2010).

Overwintering of insect pests will increase as a result of climate change, producing larger spring populations as a base for a build-up in numbers in the following season. These may be vulnerable to parasitoids and predators if the latter also overwinter more readily. Diamondback moth, *Plutella xylostella* (Linnaeus) overwintered in Alberta in 1994, and if overwintering becomes common, the status of this insect as a pest in North America will increase dramatically (Dosdall, 1994). Many insects such as *Helicoverpa* spp. are migratory and, therefore, may be well adapted to exploit new opportunities by moving rapidly into new areas as a result of climate change. There may also be increased dispersal of airborne insect species in response to atmospheric disturbances.

Effect of Temperature on Insects

The rate at which most insect pests develop is dependent on temperature as insects are poikilothermic (Deka *et al.*, 2009). Thus, temperature is probably the single most important environmental factor influencing insect behaviour, distribution, development, survival and reproduction and every species has a particular 'threshold temperature' above which development can occur. It has been estimated that with a 2°C temperature increase, insects might experience 1-5 additional life cycles per season (Yamamura and Kiritani, 1998). This effect may be most noticeable in insects with short life cycles such as aphids and diamondback moth.

It was predicted that *Chilo suppressalis* (Walker), which is presently confined to the easternmost part of Hokkaido Island, would occur throughout Hokkaido and produce two generations a year after 2°C warming. The outbreaks of *C. suppressalis* are taking place in association with cool and wet summers or in July, because of the high survival rate of the first generation larvae. The expansion of its distribution ranges has usually occurred through increased density mediated by increased reproduction. As long as *C. suppressalis* remains at the current low population density under the conditions of global warming, the northward range expansion of this species would scarcely be expected (Morimoto *et al.*, 1998; Kiritani and Morimoto, 2004).

Under a warmer climate at mid-latitudes there would be an increase in the overwintering range and population density of a number of important agricultural pests, such as the potato leafhopper which is a serious pest of soybeans and other crops in the USA. Assuming planting dates did not change, warmer temperatures would lead to invasions earlier in the growing season (i.e. at more susceptible stages of plant development) and probably lead to greater damage to crops. In the US corn belt, increased damage to soybeans is also expected due to earlier infestation by the corn earworm, which could result in serious economic losses. Temperature increases already have caused changes in species diversity and distribution. For example, the mountain pine beetle, a major forest pest in the United States and Canada, has extended its range northward by approximately 300 kilometers with the temperature increase of approximately 1.9°C (Dhaliwal *et al.*, 2013).

Under the climatic changes projected by the Goddard Institute for Space Studies general circulation model, northward shifts in the potential distribution of the European corn borer of up to 1220 km are estimated to occur, with an additional generation found in nearly all regions where it is currently known to occur (Porter *et al.*, 1991).

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Effect of Co_2 on Insects

Insect host plant interactions will change in response to the effects of CO_2 on nutritional quality and secondary metabolites of the host plants. Increased levels of CO_2 will enhance plant growth, but may also increase the damage caused by some phytophagous insects (Gregory *et al.*, 2009). In the enriched CO_2 atmosphere expected in the next century, many species of herbivorous insects will confront less nutritious host plants that may induce both lengthened larval developmental times and greater mortality (Coviella and Trumble, 1999).

A gradual continual rise in atmospheric CO_2 will affect pest species directly (CO_2 fertilization effects) and indirectly (via interactions with other environmental variables). The CO_2 effects on insects are usually indirect in terms of insect damage that results from changes in the host crop. Among the probable effects of elevated atmospheric CO_2 are changes in plant nitrogen balance that will adversely affect host plant quality for many herbivorous insects (Coviella and Trumble, 1999). Plants grown in elevated CO_2 typically have lower N content per unit of plant tissue. This results in higher C/N. Insects that feed on plants with lower N per unit of plant tissue generally respond by increasing consumption, but may still suffer longer developmental times and higher mortality (Wier and Boethel, 1995). Generally, elevated CO_2 levels induce increased consumption rates in insect herbivores (Trumble and Butler, 2009). In atmospheres experimentally enriched with CO_2, the nutritional quality of leaves declined substantially due to dilution of nitrogen by 10 to 30 per cent (Coley, 1998).

Increased CO_2 may also cause a slight decrease in nitrogen-based defenses (e.g. alkaloids) and a slight increase in carbon-based defenses (e.g. tannins). Acidification of water bodies by carbonic acid (due to high CO_2) will also affect the floral and faunal diversity (Gore, 2006). Lower foliar nitrogen content due to CO_2 causes an increase in food consumption by the herbivores up to 40 per cent, while unusually severe drought increases the damage by insect species such as spotted stem borer, *Chilo partellus* (Swinhoe) in sorghum (Sharma *et al.*, 2005). Cotton is a good example of a plant with phenolics that can reduce insect feeding. Elevated carbon dioxide levels allow many plant species to greatly increase their carbon-based defenses. For example, potatoes and plums are plants containing defensive compounds based on nitrogen.

Larval growth and development of *Spodoptera litura* (Fabricius) on groundnut plants subjected to elevated (550-750 ppm CO_2) and reduced (350 ppm in chamber and open conditions) levels of CO_2 revealed that the larvae consumed significantly higher quantity of foliage under elevated CO_2 than under reduced and ambient conditions. An increase of nearly two days in larval duration was observed with elevated CO_2 level (Reddy *et al.*, 2010). Rising carbon dioxide will increase the carbon-to-nitrogen balance in plants, which in turn will affect insect feeding, concentrations of defensive chemicals in plants, compensation responses by plants to insect herbivory, and competition between pest species (Coviella and Trumble, 1999).

Global Impact of Climate Change

Due to the enormous uncertainties surrounding global climate change, estimates of cropland reductions vary widely—from 10 to 50 per cent. But this much is clear: global warming is likely to alter production of rice, wheat, corn, soybeans, and potatoes—staples for billions of people and major food crops in both North America and Africa. By some estimates, agricultural productivity in Africa, Asia and Latin America is expected to decrease by as much as 20 per cent, with less developed countries suffering the greatest negative effects (IPCC, 2007). While climate change will have global impacts on agriculture, regional variations will be significant. Africa and North America exemplify the regional variations that may occur. These differences underscore the difficulty in proposing general strategies for adapting new agricultural technologies to deal with the climate change (Dhaliwal *et al.*, 2013).

If global warming raises the temperature 2°C in the United States and slightly less in Africa, insects will multiply and prosper. During a growing season, some insects produce 500 offsprings per female every two weeks. Rising temperatures will lengthen the breeding season and increase the reproductive rate. That, in turn, will raise the total number of insects attacking a crop and subsequently increase crop losses. In addition, some insects, such as the Southwestern corn borer, will be able to extend their range northward as a result of the warming trend. Under the projected warming trend in the United States, farmers can expect a 25 to 100 per cent increase in losses due to insects, depending on the crop. Because crop losses to insects in Africa are already high, the projected impact on different crops range from minus 30 per cent for soybeans to plus 7 per cent for rice. West Africa's warm, moist conditions are ideal for insects and crop diseases. In addition, increased atmospheric carbon dioxide is expected to alter the nutritional makeup of crops, thereby affecting the severity of attack from insects (Chippendale, 1979).

While these impacts have not been quantified, studies indicate that certain caterpillars eat more but have a higher mortality on plants grown under high CO_2 levels. Therefore, increases in crop losses from insects and diseases because of nutritional changes in crops are projected to be

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minimal. Although projected climatic conditions in Africa are different from those in North America, crop losses from pests are expected to increase because effective pest control technologies are not readily available.

USA: Most analyses concur that in a changing climate, insect pests may become even more active than they are currently, thus posing the threat of greater economic losses to farmers. With temperatures within their viable range, insects respond to higher temperature with increased rates of development and with less time between generations. (very high temperatures reduce insect longevity). Warmer winters will reduce winterkill, and consequently there may be increased insect populations in subsequent grow-ing seasons. With warmer temperatures occurring earlier in the spring, pest populations can become established and thrive during earlier and more vul-nerable crop growth stages. Additional insect gen-erations and greater populations encouraged by higher temperatures and longer growing seasons will require greater efforts of pest management (Stinner *et al.,* 1989).

Some species are pests in America's South but not in the Midwest, because they do not migrate to the Midwest early enough or in significant numbers. Corn earworm, *Helicoverpa zea* (Boddie), is an example of a current pest of corn and soybean in the South that is not a serious pest in field corn and soybean in the Midwest. With climate change, extension of overwintering range may bring the corn earworm to field corn and soybean crops in the Midwest. The damage of the European corn borer, *O. nubilalis,* a major insect pest of corn in the U.S. and elsewhere, is limited in many regions due to current climate conditions. For example, in lowa the insect has only two generations per corn-grow-ing season because the third generation pupae can not complete development before the winter. Warmer conditions will ensure a third generation of the insect and would make its overwintering population significantly larger (Stinner *et al.,* 1989).

Since warmer temperature will bring longer grow-ing seasons in temperate regions, this should pro-vide opportunity for increased insect damage. A longer growth period may allow additional gener-ations of insect pests and higher insect popula-tions. The Mexican bean beetle and bean leaf bee-tle, both major pests of soybeans, presently have two generations in the U.S. Midwest and three in the Southeast. An additional generation may be possible in the Midwest if the growing season there lengthens. The preponderance of evidence indicates that there will be an overall increase in the number of outbreaks of a wider variety of insects.

India: Conditions are more favourable for the proliferation of insect pests in warmer climates. Longer growing seasons will enable insects such as grasshoppers to complete a greater number of reproductive cycles during the spring, summer, and autumn. Warmer winter temperatures may also allow larvae to winter-over in areas where they are now limited by cold, thus causing greater infestation during the following crop season. Altered wind patterns may change the spread of both wind-borne pests and of the bacteria and fungi that are the agents of crop diseases. Crop-pest interactions may shift as the timing of development stages in both hosts and pests are altered. Some of the insect pests which are likely to assume serious proportions due to the changing climate and cropping patterns include American bollworm, *Helicoverpa armigera* (Hubner); tobacco caterpillar, *Spodoptera litura* (Fabricius); cotton whitefly, *Bemisia tabaci* (Gennadius); brown planthopper, *Nilaparvata lugens* (Stal); gall midge, *Orseolia oryzae* (Wood-Mason); pink stem borer, *Sesamia inferens* (Walker); wheat aphid, *Macrosiphum miscanthi* (Takahashi); pyrilla, *Pyrilla perpusilla* (Walker); sugarcane woolly aphid, *Ceratovacuna lanigera* (Zehntner); serpentine leaf miner, *Liriomyza trifolii* (Burgess); diamondback moth, *Plutella xylostella* (Linnaeus); rhinoceros beetle, *Oryctes rhinoceros* (Linnaeus) and tea mosquito bug, *Helopeltis antonii* Signoret. The possible increases in pest infestations may bring about greater use of chemical pesticides to control them, a situation that will require the further development and application of integrated pest management techniques (Dhaliwal *et al.*, 2010).

Japan: The results of global climate model developed by Meteorological Research Institute indicated the abundance of insect pests in the averaged climate from 2031 to 2050. Rice stem borer was projected to increase by a factor of 1.6, while green rice leafhopper was projected to increase by a factor of 30. Global warming increases the yield loss caused by insect pests in paddy field (Yamamura *et al.*, 2006)

Europe: A change from chemical control to very advanced integrated pest management programs (IPM) in European greenhouses took place at the end of the last century. For the main greenhouse vegetable crops in northern Europe, most insect problems can now be solved without the use of insecticides. IPM without conventional chemical pesticides is a goal that will be realized for most of the important vegetables in Europe, not limited to greenhouse vegetables. At the same time, however, climate change affects the distribution, phenology, susceptibility and the interrelationship of insects drastically, which emphasize

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the risk of sustainable crop protection by loosing the control on pests - natural enemies populations. Mean annual temperature changes between 3 and 6°C are estimated to occur across Europe, with greatest increases occurring at high latitudes. An increase of 6°C in temperature, and precipitation deficit of 300 nm reduced the maize yield by 36 per cent in the European Union. Under the climatic changes projected by the Goddard Institute for Space Studies general circulation model, northward shifts in the potential distribution of the European corn borer of up to 1220 km are estimated to occur, with an additional generation found in nearly all regions where it is currently known to occur (Lenteren, 2000; Kogan and Jepson, 2007).

China: In accordance with the general trend of global climate change, surface air temperature in China has increased by 1.1° C over the last 100 years. More significant increase occurred in the recent 50 years. Model predictions have suggested that the surface air temperature in China will probably increase by 1.5-2.8° C by 2030, and 2.3-3.3° C by 2050. Rice production in China is likely to benefit from global warming due to the extended length of rice growing season that allows earlier planting and later harvesting, the reduction of low- temperature injury, and the northward expansion of rice planting area, while the increasing insect pests and water demand must be recognized and managed (Huang *et al.*, 2009).

Nepal: With an average of 0.06°C/year, a rise in temperature from 1975 to 2006 by 1.8°C has been recorded in Nepal. Problem of frequent drought, severe floods, landslides and mixed type of effects in agricultural crops have been experienced because of climate change. Studies conducted on CO_2 enrichment technology at Khumaltar revealed that the yield of rice and wheat increased by 26.6 and 18.4 per cent due to double CO_2 and 17.1 and 8.6 per cent due to increase in temperature, respectively. A crop simulation model (DSSAT) to study the effects of CO_2, temperature and rain in NARC showed positive effect on yield of rice and wheat in all regions, but negative effect on maize especially in Terai. Climate change parameters: temperature, rainfall pattern and humidity have an impact on the development and distribution of pests. Increase in temperature and CO_2 will lead to an increase in population of pests in presence of host plant. It increases the rate of reproductive cycle of insect. The increase in insect population leads to demand for more use of pesticides, which unknowingly causes lots of harm to ecosystem as well as human society. Incidence of pests would be most severe in tropical region due to climate change. Insect pests and diseases of plain ecosystem may gradually shift to hills and mountains (Malla, 2008).

Pest Management Strategies

Host plant resistance, microbial pesticides, natural enemies, and synthetic chemicals are some of the potential options for integrated pest management. However, the relative efficacy of many of these pest control measures is likely to change as a result of influence of global warming on extension of geographical range of insect pests, increased over-wintering and rapid population growth, changes in insect – host plant interactions, increased risk of invasion by migrant pests, impact on arthropod diversity and extinction of species, changes in synchrony between insect pests and their crop hosts, introduction of alternative hosts as green bridges, and reduced effectiveness of crop protection technologies.

Host Plant Resistance: Host plant resistance to insects is one of the most environmentally friendly components of pest management. However, climate change may alter the interactions between the insect pests and their host plants (Bale *et al.,* 2002). Global warming may also change the flowering times in temperate regions, leading to ecological consequences such as introduction of new insect pests, and attaining of a pest status by non-pest insects (Willis *et al.,* 2008). However, many plant species in tropical regions have the capability to withstand the phenological changes as a result of climate change. Global warming may result in breakdown of resistance to certain insect pests. Sorghum varieties exhibiting resistance to sorghum midge, *Stenodiplosis sorghicola* (Coquillett), in India become susceptible to this pest under high humidity and moderate temperatures near the Equator in Kenya (Sharma *et al.,* 1999). There will be increased impact on insect pests which benefit from reduced host defenses as a result of the stress caused by the lack of adaptation to sub-optimal climatic conditions. Chemical composition of some plant species changes in direct response to biotic and abiotic stresses; as a result, their tissues become less suitable for growth and survival of insect pests. However, problems with new insect pests will occur if climatic changes favor the introduction of insect susceptible cultivars or crops. The introduction of new crops and cultivars to take advantage of the new environmental conditions is one of the adaptive methods suggested as a possible response to climate change (Sharma, 2010).

Insect-host plant interactions will change in response to the effect of CO_2 on nutritional quality and secondary metabolites of the host plants. Plants, grown under low-nutrient conditions, do have higher concentrations of carbon-based allelochemicals than plants grown under high-nutrient conditions. Host plants growing under enriched-CO_2 environments exhibited significantly larger biomass

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(+38.4%), increased C/N ratio (+26.57%), and decreased nitrogen concentration (-16.4%), as well as increased concentrations of tannins (+29.9%) and other phenolics (Heagle, 2003). In contrast to the C/N balance hypothesis, plants grown in elevated (700 ppm) CO_2 conditions had similar, or lower concentrations of carbon-based allelo-chemicals than plants grown in ambient (350 ppm) CO_2 conditions. Larvae fed with foliage grown in elevated CO_2 with low N fertilization consumed significantly more plant material than insects fed with foliage grown in ambient CO_2; but, again, no differences were observed with high N fertilization and the insects fed on low N plants had significantly higher mortality in elevated CO_2 (Coviella and Trumble, 2000).

The production of the nitrogen-based toxin was affected by an interaction between CO_2 and N; elevated CO_2 decreased N allocation but the reduction was largely alleviated by the addition of nitrogen, thus indicating that future expected elevated CO_2 concentrations by climate change, alter plant allocation to defensive compounds and have enough impact on plant-herbivore interactions. Increases of carbon-defensive compounds by elevated CO_2 or low N availability or both, adversely affected growth and survival of *Spodoptera exigua* (Hubner) in Bt cotton. It was observed that feeding guild, in which some species have shown increases in population density in elevated CO_2, are the phloem feeders. It is likely that climate change will not minimize the outbreaks; on the contrary, it might benefit some pests, which might increase the consumption of pesticides. Chewing insects have shown no change or reduction in abundance, though relative abundance may be greatly affected since compensatory feeding is common in these groups (Carlos *et al.*, 2002).

Transgenic Crops: Environmental factors such as soil moisture, soil fertility, and temperature have strong influence on the expression of *B. thuringiensis* (Bt) toxin proteins deployed in transgenic plants (Sachs *et al.*, 1998). Cotton bollworm, *Heliothis virescens* (Fabricius) destroyed Bt-transgenic cottons due to high temperatures in Texas, USA (Kaiser, 1996). Similarly, *H. armigera* and *H. punctigera* (Wallengren) destroyed the Bt-transgenic cotton in the second half of the growing season in Australia because of reduced production of Bt toxins (Hilder and Boulter, 1999). Cry1Ac levels in transgenic plants decrease with the plant age, resulting in greater susceptibility of the crop to insect pests during the later stages of crop growth. Possible causes for the failure of insect control in transgenic crops may be due to inadequate production of the toxin protein, effect of environment on transgene expression, Bt-resistant insect populations, and development of resistance due to inadequate management (Sharma and Ortiz, 2000). It is, therefore, important to understand the effects of climate change on the efficacy of transgenic plants for pest management.

Natural Enemies: Climate change can have diverse effects on natural enemies of pest species. The fitness of natural enemies can be altered in response to changes in herbivore quality and size induced by temperature and CO_2 effects on plants. The susceptibility of herbivores to predation and parasitism could be decreased through the production of additional plant foliage or altered timing of herbivore life cycles in response to plant phenological changes. The effectiveness of natural enemies in controlling pests will decrease if pest distributions shift into regions outside the distribution of their natural enemies, although a new community of enemies might then provide some level of control. The abundance and activity of natural enemies will be altered through adaptive management strategies adopted by farmers to cope with climate change. These strategies may lead to a mismatch between pests and enemies in space and time, decreasing their effectiveness for biocontrol (Thomson *et al.*, 2010).

Relationships between insect pests and their natural enemies will change as a result of global warming, resulting in both increases and decreases in the status of individual pest species. Changes in temperature will also alter the timing of diurnal activity patterns of different groups of insects (Young, 1982), and changes in interspecific interactions could also alter the effectiveness of natural enemies for pest management. Quantifying the effect of climate change on the activity and effectiveness of natural enemies for pest management will be a major concern in future pest management programs. Oriental armyworm, *Mythimna separata* (Walker) populations increase during extended periods of drought (which is detrimental to the natural enemies), followed by heavy rainfall because of the adverse effects of drought on the activity and abundance of the natural enemies of this pest (Sharma *et al.*, 2002). Aphid abundance increases with an increase in CO_2 and temperature, however, the parasitism rates remain unchanged in elevated CO_2. Temperatures up to 25°C will enhance the control of aphids by coccinellids. Temperature not only affects the rate of insect development, but also has a profound effect on fecundity and sex ratio of parasitoids (Dhillon and Sharma, 2009).

Effects of predators can be encouraged or discouraged by temperature increases. For instance, below 11°C, the pea aphid reproduction rate exceeds the rate at which the lady bird beetle, *Coccinella septempunctata* Linnaues, can consume it. Above 11°C, the situation is reversed. In contrast,

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natural enemies of the spruce budworm, *Choristoneura fumiferana* (Clemens), are less effective at higher temperatures (Harrington *et al.*, 2001). The growth and development of insect herbivores varied with the nutritional quality of their diet (host plant) and the dietary differences showed varied effects on parasitoids. The population size of the insects significantly differed under elevated CO_2 and in turn influencing the insect fecundity. Thus, any dietary differences that prolong developmental time, increase food consumption, and reduce growth by herbivores serve to increase the susceptibility of herbivores to natural enemies (Roth and Lindroth, 1995).

Increasing CO_2 concentrations could alter the preference of lady beetle to aphid prey and enhance the biological control of aphids by lady beetle in cotton crop. This study provided the first empirical evidence that changes in prey reared on host plant grown at different levels of CO_2 altered the feeding preferences of the predator. Some studies suggest that higher temperatures increase the probability that a host will kill its parasitoid. For instance, parasitism of the caterpillar, *Spodoptera littoralis* (Boisduval), by the parasitoid, *Microplitis rufiventris* Kak, is less efficient at 27°C than at 20°C (Thomas and Blanford, 2003).The interactions between insect pests and their natural enemies need to be studied carefully to devise appropriate methods for using natural enemies in pest management.

Microbial Biopesticides: There will be an increase in variability in insect damage as a result of climate change. Higher temperatures will make dry seasons drier, and conversely, may increase the amount and intensity of rainfall, making wet seasons wetter than at present. Natural plant products, entomopathogenic viruses, fungi, bacteria, and nematodes, and synthetic pesticides are highly sensitive to the environment. Although microbial biopesticides are among the widely used ecofriendly methods of pest control, their efficiency is highly variable across micro-organisms with the change in climatic factors. The available information indicated that high relative humidity is associated with high mortality in host insects infected with fungal and viral pathogens, however, such effects on host infected with bacteria are variable, as environmental influence on host-pathogen interactions operates through biology of the pathogen, immune response of the host. Temperature, relative humidity, elevated atmospheric CO_2, UV radiation, pH, rainfall, soil moisture, etc., are the most influential climatic factors determining the efficiency of microbial biopesticides. Therefore, there is greater need to understand their interactions with biopesticides, identify robust and adaptive microbial strains, modify their beneficial traits as per the requirements using molecular techniques and devise appropriate formulations and strategies for their effective use in insect pest management under diverse array of environmental conditions (Abbaszadeh *et al.*, 2011).

Toxins from *B. thuringiensis* have been used as pest management tools for more than 50 years. The effect of these toxins depends on the quantity of Bt toxins ingested by susceptible insects. Food ingestion is affected by CO_2 concentration; plants grown in elevated CO_2 often have increased carbon/nitrogen ratios (C/N), resulting in greater leaf area consumption. Elevated CO_2 would improve the efficacy of foliar applications of *B. thuringiensis* (Coviella and Trumble, 2000).

Botanical Pesticides: Among the botanical pesticides, azadirachtin- an important limnoid of neem tree (*Azadirachta indica* A. Juss.) has been found to be quite promising. However, the azadirachtin content of neem tree is highly variable across genotypes, regions, habitats, fruit bearing season and climatic conditions. The neem genotypes belonging to coastal, arid and semi- arid ecosystems synthesize higher azadirachtin A content than those from the sub-humid regions. The neem trees growing in Andhra Pradesh, Karnataka, and Tamil Nadu in India synthesize higher azadirachtin content as compared to those growing in Orissa, Delhi, and Rajasthan; whereas those growing in Maharashtra, Madhya Pradesh, Uttar Pradesh and Punjab produce intermediate azadirachtin. The neem trees growing in hot sub-humid, hot arid, and hot semi-arid with cold winter regions synthesize lower azdirachtin content compared to those grown in hot semi-arid with mild winter region, indicating that moderate climatic conditions are favourable for azadirachtin synthesis as compared to extreme climatic condition (Abbaszadeh *et al.*, 2011).

Similarly, there are significant variation in azadirachtin content of neem seeds of Asia and African origin. The neem seeds of Nicaragua and Indonesia produced more azadirachtin followed by those from India, Myanmar and Mauritius. It has been found that the winter stress favours synthesis of azadirachtin B and F in the neem tree seeds. Moreover, azadirachtin A is highly influenced by environmental factors compared to oil in the seeds and a significant and positive correlation was found for azadirachtin A and oil content with relative humidity, and significant and negative association with atmospheric temperature. The neem genotypes bearing fruits in November produce 2-4 times more azadirachtin A than those producing fruits in July, suggesting that the neem tree genotypes bearing fruits in November should be identified and commercially deployed for producing neem based biopesticide formulations (Gupta *et al.*, 2010)

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CONCLUSIONS

The following strategies are suggested to mitigate the effects of climate change on insect pests and their management.

- Careful monitoring of pest damage, including associated pathogen and insect populations should be carried out. This would be the first step in a strategy to understand and deal with the effect of global climatic changes as they occur. The acquired knowledge would provide tools to enhance resistance/tolerance to biotic stresses, which would lead to improved IPM and sustained crop productivity.
- There is a need to develop of prediction models for insect pest outbreaks and understand the influence of climatic change on species diversity and cropping patterns, and their influence on the abundance of insect pests and their natural enemies.
- Transgenic crops are likely to play a prominent role in future IPM programmes. Therefore, studies on the effect of climate change on the efficacy of transgenic crops should receive priority.
- Studies on the expression of resistance/virulence genes under different temperature regimes, and the identification and use of resistance genes that are stable under high temperature regimes, should be intensified.
- The possible increased use of insecticides resulting from an increase in pest outbreaks will likely have negative environmental and economic impacts for agriculture. The best economic strategy for farmers to follow is to use integrated pest management practices to closely monitor insect occurrence. Keeping pest and crop management records over time will allow farmers to evaluate the economics and environmental impact of pest control and determine the feasibility of using certain pest management strategies or growing particular crops.

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Safer Management Strategies for Okra Pests with Emphasis on Under-storey Repellent Crop

S. Chakraborti[1]*, P.K. Sarkar[1], A.R. Mandal[2] and Arunabha Chakraborty[3]

[1]Department of Agricultural Entomology,
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur 741252, Nadia, West Bengal, India
[2]Department of Vegetable Crops [3]PhD Scholar
**E-mail: cssento@gmail.com*

Abstract: Some safer management strategies for okra insect pests were evaluated. It was designed emphasizing on the repellent crop theory and the components like physical barrier, trapping, plant sanitation and foliar application of phytochemicals integrated with it expecting greater impact on pest suppression and lower crop damages. The strategies effectively suppressed the landing response and development of the pest populations, crop damages, sponsored good yields, were safer to non-target beneficial creatures, cost-effective and at par with chemical method.

Key words: Okra, pests, safer management, yield, beneficial

Protecting okra plants against the pests through chemical method is a commonly adopted and widely preferred approach (www.ncipm.org.). It is also not uncommon that the farmers are applying pesticides once in every two or three days. It is now well-known that synthetic organic pesticides invite a large number of serious unintended consequences like environmental contamination, health hazards, instability of ecosystem, destruction of beneficial creatures, huge accumulation in biological systems, pesticide resistance, resurgence and replacement of pests, apart from the prohibitive cost of protection (Ramanjaneyulu *et al*., 2009). This sequence has pushed the entire farming community into a strange puzzle that requires immediate and stable solution. Search for the safer, stable and effective solution needs a system approach which considers the pests, plants and ecosystem altogether. Pest problem begins only after arrival of the pest on the target plants and hence, measures or approaches that deters or discourages pest arrival and its population development, in principle, should result in effective pest suppression. Keeping that aspect in mind, a pest management module was designed which emphasized on the role of repellent crop in deterring pest arrival and /or population development on okra. An assessment of the impact of the pest management modules on non-target beneficial creatures of the okra ecosystem was also made.

MATERIAL AND METHODS

The experiments were carried out at farm fields in the new alluvial zone, North 24 Parganas, West Bengal, India during summer seasons of 2011 and 2012. These were set out in randomized block design with four treatments including one untreated check, replicated four times in plots of 5m x 4m size. Crops were sown on 18th February and the plantations were maintained for 100 days. Standard agronomic practices were followed to ensure optimal crop stand. To prepare rose apple leaf extract, five kg fresh leaves were crushed in a blender and added to five litres of hot water (100°C) (1:1 w/v). This mixture was kept in the shade for twenty four hours. A clear extract was obtained by sieving. This extract was used as the stock solution. The following components were utilized as common blanket for the treatments T1, T2 and T3 - (a) Yellow sticky traps (50 cm x 25 cm) set above canopy level (b) repellent crop strips: 20 cm-wide strips of coriander, basil and tagetes (1:1:1) between rows of okra plants (c) Maintenance of plant sanitation - removal of broken or twisted branches and maintenance of clear basal stems (20 cm or more) (d) neem cake at land preparation @ 200 kg/ha. Red colored nylon net cover (top) was provided for the entire experimental field. Foliar treatments were applied as MV sprays @ 500 litres/ ha. Neem oil was applied adding a tinge of common detergent and removing brown froth after mixing in water. The treatments were: T1 (neem oil)-Prophylactic application of neem oil @ 7ml/litre, started at 15 days after sowing (DAS) and continued at 7 day interval up to harvest; T2 (rose apple LE)-Prophylactic application of rose apple LE @ 100 ml/litre, started at 15 DAS and continued at 7 day interval up to harvest; T3 (neem oil + rose apple LE) - Prophylactic application of the mixture of neem oil @ 7ml/litre + rose apple LE @ 100ml/litre (1:1), started at 15 DAS and continued at 7 day interval up to harvest; T4 (Chemical check/ farmers' practice) – alternated sprays of thiamethoxam 25 WG @ 2ml ai/l and carbaryl 50 WP @ 2.5 g ai/l at weekly

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interval starting from 15 DAS and continued till harvest. Observations on the number of white fly, jassid, aphid and thrips were also taken at 10-day-interval starting from 15 days after sowing (DAS); these were taken from randomly selected three leaves per plant (upper, middle and lower canopy zones) @ 4 plants per plot, excluding the border ones. For leaf roller, all the leaves of 4 randomly selected plants per plot were examined and the number of larvae and per cent infested leaf were worked out. For spotted borer infestation, all the fruits were examined at each harvest and the mean per cent damage was worked out. Fruiting started between 40-42 DAS and no fruit was produced by any plant on or before 30DAS. All the fruits were counted at the time of harvest and data on other physical parameters were also recorded at that time. Fruit numbers were progressively summed up. Fruit weights were also progressively summed up to get yield per plant and per hectare. Record on the natural enemies was taken from randomly selected 4 plants per plot while pollinators (bumble bee and honey bee) were recorded from the entire plot starting from 30 DAS at 15 day-intervals. Natural enemies included general predators like spiders (six species), coccinellids (five species) and syrphid (one species) and immature and mature stages were counted altogether. Increase in yield over the treated check (farmers' practice) was calculated using the following standard formula:

$$\text{Increase (\%)} = \frac{\text{Yield in treatment} - \text{Yield in treated check}}{\text{Yield in treated check}} \times 100$$

Collected data were then subjected to pooled analysis of variance and the treatments were compared at 5% level of significance following F test.

RESULTS AND DISCUSSION

The data presented in Table 1 showed that the treatments were effective in checking the population development and damages of the important pests on okra. Management modules were designed emphasizing the role of repellent crops in suppressing or deterring pest populations so that resultant crop damage is minimized. The three treatments (T1, T2, and T3) recorded a low and slow development of white fly populations (0.6 – 2.3/leaf) over a period of 90 days and were significantly superior to chemical check (4.5 white flies/leaf). Apparently, development of pesticide tolerance in the white fly populations is the most likely reason for it. Three other sucking pests (jassid, aphid, and thrips) also can cause substantial damage under unrestricted growth option but all the treatment modules effectively checked their population development. However, chemical check (T4) was significantly superior to all the three treatments. The most important insect pest in the present study was the spotted bollworm (*Earias* sp.) and performance of the treatments (T1, T2, T3) was quite satisfactory, recording 6.1 – 8.7 per cent infested fruit and although chemical check produced little better result (5.2% infested fruit), T3 (neem oil + rose apple LE) was at par with it. Impact of the treatment on another lepidopteran, the leaf roller, was also of similar pattern (0.8 – 1.6 larvae/plant; 4.2 – 5.4% rolled leaves) and chemical check was significantly superior (0.2 larva/plant; 2.4% rolled leaves) to all the treatments. Effect of the treatments was reflected in the yield attributes like fruit number, fruit weight, fruit length and yields (Table 3) of the treatments (T1, T2, T3) (9.94 – 10.26 t/ha; 316 – 328 g/plant) and was fairly good and at par with chemical check (10.44 t/ha; 334 g/plant). The ultimate balance sheet for pest management reflects in the cost-economics and two treatments, T1 (neem oil; CBR: 2.4) and T3 (neem oil + rose apple LE; CBR: 2.6), offered better cost-benefit ratio (CBR) over chemical check which had 12 rounds of sprays. Results (Table 2) also indicated that all the treatments were safe to the natural enemies and pollinators found in the okra ecosystem and were at par. Chemical check (T4), on the other hand, was found toxic to predatory coccinellids, spiders, syrphids and honey bees but bumble bees were apparently less affected. The pest management module was designed emphasizing the active role of *'anti-insect plant factor'* because plant volatiles are known to play an important role in the host selection process. In the present studies, mixed strips of three plant species were incorporated: basil-tagetes-coriander in 1:1:1 ratio. Rationale was to musk the volatiles of the host plant so that the pests fail to recognize their host and this will translate into lower intensity of infestation and damage. All three plant species contain a number of flavonoids, saponins, phenols and essential oils which produce the characteristic aroma for them (Kitajima *et al.*, 2003; http://organicgardening.about.com; Laakso *et al.*, 1990). Allelochemicals secreted by plants either attract or repel insect pests and influence their landing response (Finch and Collier, 2003). In the present study, the allelochemicals secreted by okra, basil, marigold and coriander got mixed up in the air, created confusion in pest populations and their sensory systems failed to detect the host plants which resulted in inferior landing response; that means, coriander-basil-tagetes combination successfully acted as repellent crop group. Red-colored nylon net was included as the component primarily for three reasons: disruption in the host selection process by the insects which are attracted by green canopy, encouraging inappropriate landing and as physical barrier to flying adults. This contributed to inferior landing response

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and lower count of the pest populations. Plant sanitation was maintained through periodic removal of older leaves and broken or twisted branches along with pest populations (specially, whitefly, aphid, thrips and jassid) and maintenance of clear basal stems (20 cm or more). These factors directly lowered the pest population densities and their damages. Yellow sticky traps were set above canopy level to catch insects like jassid, thrips, white fly and alate aphids. The treatment compliments either discouraged the insects to move into field or removed them at the very beginning of the population build up. It means, inferior landing response coupled with inappropriate landing response, interruption in host selection process, antifeedant and repellent action of phytochemicals, physical removal through sticky trap, net barrier and phytosanitation resulted in suppression of pest populations and their damages. Neem oil is known to contain a number of biologically active principles (alkaloids) and it had shown repellency, antifeedancy, anti-growth activities and direct toxicity against a number of insects (Schumutterer, 1990; Chakraborti and Chatterjee, 1999). Plant fractions of rose apple is also known to contain a number of biologically active principles like jambosine, hydrocyanic acid, ellagic acid and terpenoids like pinene, limonene, ocimene, á-pinene, camphene, limonene, cadinene, borneol and á-terpineol. Some of these phytochemicals are toxic while some others have strong aroma (Chakravarty *et al*., 1998; Hoang and Nguyen, 2004). The active principles definitely also acted as feeding deterrent to the insect populations. Impact of the treatments on the predatory fauna in okra ecosystem showed that all the treatments, except chemical check, were safe to predatory populations as observed at different DAS which included six species of spiders, five species of coccinellids and one species of syrphid (*Syrphus* sp.) and the treatments were statistically at par (Table 3). Chemical check appeared unsafe for the generalist predators like spiders and coccinellids, highly toxic for the syrphids and actually, wiped away their populations as observed on 50 DAS onward. Following treatment, the predators in chemical check migrated and at least some of them and/or new populations moved into those plots which actually showed the countable numbers. Syrphids did not like the treated plants and avoided contaminated plant surfaces and this coupled with direct mortality explains why syrphids were not found in chemical check. Okra ecosystem supports rich populations of different bee species by providing good amount of pollens as well as nectar. Hence, bee toxicity of the pesticides and adverse impact of the pest management practices on bee populations are critically important. In the present study, chemical check was toxic to honey bees (*Apis* sp.) but bumble bees (*Bombus* sp.) were apparently not affected

Table 1. Effect of treatments on mean population development and damages of some important sect pests on okra plants

Treatment	Whitefly per leaf at days after sowing (DAS)					Jassids /leaf	Thrips /leaf	Aphids /leaf	Spotted borer infested fruit (%)	Leaf roller infestation	
	10 DAS	30 DAS	50 DAS	70 DAS	90 DAS					Larvae per plant	Rolled leaves/ plant (%)
T1 - Neem oil	-	0.8	0.6	1.1	1.7	1.2	2.8	3.4	7.2 (15.56)	1.4	4.2(11.83)
T2 – Rose Apple Leaf Extract	-	0.9	1.2	1.9	2.3	1.8	3.2	3.8	8.7(17.16)	1.6	5.4(13.44)
T3 – Neem Oil + Rose Apple Leaf Extract	-	0.6	0.7	0.9	1.5	1.1	2.7	3.2	6.1(14.30)	0.8	4.6(12.39)
T4 - Chemical check	-	0.9	2.7	3.3	4.5	0.2	1.6	0.2	†5.2(13.18)	0.2	2.4(8.91)
CD (p=0.05)	-	NS	0.94	1.02	1.21	0.84	1.12	0.86	(1.12)	0.52	(1.31)

† Figures in parentheses are arcsine √p transformations

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Table 2. Effect of treatments on mean population of the beneficial insects and spiders in okra ecosystem

Treatment	Coccinellids/plant	Spiders/plant	Syrphids/plant	Honey bee/plot	Bumble bee/plot
T1 - Neem oil	6.5	5.4	1.6	10.6	2.5
T2 – Rose Apple Leaf Extract	6.4	5.6	1.5	10.2	2.8
T3 – Neem Oil + Rose Apple Leaf Extract	6.9	5.5	1.7	10.8	2.4
T4 - Chemical check	2.8	2.1	-	5.2	2.3
CD (p=0.05)	1.04	1.06	0.24	0.87	0.27

Table 3. Effect of treatments on the mean attributes and yield of the okra plants and cost-benefit ratio (CBR)

Treatment	Mean Fruit number/ plant	Mean Fruit length (cm)	Mean Fruit weight (g)	Mean Plant height (cm)	Yield (tonnes/ ha)	Increase (+) or decrease (-) in yield over treated check (%)	Mean yield / plant (g)	CBR
T1 - Neem Oil	18.6	14.2	16.5	86.5	10.18	(-) 2.49	322	1:2.4
T2 – Rose Apple Leaf Extract	18.2	14.1	16.4	85.7	9.94	(-) 4.78	316	1:1.8
T3 – Neem Oil + Rose Apple Leaf Extract	19.1	14.5	16.7	86.8	10.26	(-) 1.72	328	1:2.6
T4 - Chemical check	19.4	14.3	16.8	87.4	10.44		334	1:2.1
CD (p=0.05)	2.74	1.54	0.68	0.92	1.04		3.58	

(Table 2). Treatments based on the plant extracts like neem oil (T1), rose apple LE (T2) or its combination (neem oil + rose apple LE) (T3) were safe for both the bee species. Bee numbers were consistent in these treatments, though increase rate was very slow; some bees emigrated while some others immigrated and overall impact showed a steady population. Chemical check (T4) was toxic for honey bees but bumble bees were able to withstand the toxicant impact better because of their much higher body weight as compared to honey bees and this explains why bumble bees were apparently not affected. Results showed that the rationally designed pest management module for the okra pests which emphasized on exploiting the *repellent crop theory* was effective, sustainable, safer, and cost-effective and in general agreement with some earlier works (Sardana *et al*., 2008; www.ncipm.org).

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Oviposition and Feeding Response of *Sogatella furcifera* (Horvath) on Rice Varieties with Different Levels of Resistance

Ramanpreet Kaur, K.S. Suri* and Gursharan Singh

Department of Entomology
Punjab Agricultural University, Ludhiana – 141 004, India
**E-mail: kssuri@pau.edu*

Abstract : Oviposition and feeding response of the whitebacked planthopper, *Sogatella furcifera* (Horvath), a serious insect pest of rice, was studied on rice varieties with different levels of resistance *viz. TN 1* and PR 114 (susceptible); PR 108 and PAU 201 (moderately resistant); and NCS 2041 and ARC 6248 (resistant). Oviposition by the hopper females confined for 24 hours on each variety, was maximum on *TN 1* (110.75 eggs/5♀) followed by PR 114 (100.0 eggs/5♀) while, minimum on NCS 2041 (87.75 eggs/5♀). Differential preference of the hopper for food was observed for different rice varieties. The quantity of food assimilated and ingested by *S. furcifera* on the resistant/moderately resistant rice varieties, ranging from 0.38-3.56 mg/5♀ and 16.46-36.96 mg/5♀, respectively was significantly less than on the susceptible varieties (4.97-5.71 mg/5♀ and 70.47-78.21 mg/5♀, respectively). The WBPH females excreted highest amount of honeydew when allowed to feed on *TN 1* (72.50 mg/5♀) followed by PR 114 (65.50 mg/5♀) while lowest amount was excreted on NCS 2041 (16.00 mg/ 5♀).

Key Words: *Sogatella furcifera*, rice, behaviour, oviposition, feeding, resistance

Rice planthoppers, especially the whitebacked planthopper (WBPH), *Sogatella furcifera* (Horvath) and the brown planthopper, *Nilaparvata lugens* (Stal.) are the major delphacid hoppers attacking rice in India. WBPH is recognised as one of the five major insect pests of national importance, responsible for significant decline in yield of rice in different cropping system zones of the country (Pasalu *et al.*, 2006). Both nymphs and adults suck the plant sap which result in yellowing of leaves, reduced vigour, stunting, delayed tillering, unfilled grains and yield loss. Severe infestations can lead to 'hopper-burn'. Additionally, WBPH has recently been reported to transmit the fijivirus, *Rice black streak dwarf* virus-2 (RBSDV-2) (Zhang *et al.*, 2008) and the *Southern rice black streaked dwarf* virus (SRBSDV) (Zhou *et al.*, 2008) in hybrid rice in China's southern provinces. The rapid spread of these new viruses in hybrid rice is causing concern in rice growing countries. WBPH is amenable to control with insecticides but their repeated applications often result in problems such as induction of resurgence and development of resistance (Singh *et al.*, 2008; Suri and Singh, 2011). Hence, incorporation of resistance has been a major objective of the rice improvement programme in nearly all rice growing countries. Host plant resistance is often used as a fundamental component of an integrated pest management system, as an alternative approach to cope up with the pest threats because of the generally compatible, complementary role that pest-resistant crop plays with other tactics (Gu *et al.*, 2008). The present study on oviposition and feeding preference of the *S. furcifera* to rice varieties with different levels of resistance was therefore, undertaken to obtain a better understanding on insect-plant interactions during selection of their host plant.

MATERIAL AND METHODS

The experiments to study influence of rice varieties with different levels of resistance on the oviposition and feeding of *S. furcifera* were conducted in WBPH Screen-house and Insect Physiology laboratory of the department of Entomology at the Punjab Agricultural University, Ludhiana during the years 2010 and 2011.

The response of *S. furcifera* reared and maintained on the month old potted plants of susceptible rice variety, *Taichung Native*-1 was studied on 30-days old potted plants of the six test rice varieties, PR 114 and *TN* 1 (susceptible); PR 108 and PAU 201 (moderately resistant); and NCS 2041 and ARC 6248 (resistant). For studying oviposition response of the WBPH, five gravid female hoppers were released on potted plants of each test variety enclosed in a cylindrical Mylar film cage (about 90 cm tall and 18 cm in diameter) (Plate 1). The females were allowed to oviposit for 24 hours, after which they were removed and the number of eggs laid on plants of each test variety was recorded by adopting the technique developed by Khan and Saxena (1986). The plant parts with eggs were boiled in water for 5-7 minutes to coagulate the yolk of eggs and also partially bleach the plant. For further bleaching, boiled plants were kept in 95 per cent ethyl alcohol for three days, then rinsed in water and immersed in 0.1 per cent aqueous acid fuchsin solution. After two days, the plants were washed under

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running water until stained hopper eggs were differentiated from the de-stained plant tissue. Eggs were then counted under a 20× binocular microscope. The experiment was replicated three times, each replication comprising of two plants of a variety per pot.

Feeding of the planthoppers has been directly correlated to the excretion of honeydew by hoppers (Sogawa and Pathak, 1970). For studying the feeding response of *S. furcifera*, the parafilm sachet technique (Heinrichs *et al.*, 1981) was employed. A parafilm sachet (5 cm × 2.5 cm) was fixed tightly around the basal part of the stem of 30-days old test variety (Plate 2), so as to allow a minimum of air to enter into the sachet. Five newly emerged, two hours starved but water-satiated female hoppers were anesthetized using carbon dioxide gas, weighed on a microbalance and released into each sachet after they revived, and confined therein for 24 hours. The hoppers while feeding on the test plants excreted honeydew, which collected as clear droplets on the inner side of the sachet. After 24 hours, this sachet with hoppers and honeydew was removed by cutting it parallel to the stem. The hoppers were anesthetized and weighed again. The sachet containing honeydew was weighed on an electronic microbalance. After removing honeydew with a filter paper, the sachet was again weighed. The differences in the weight of the sachet before and after removing the honeydew gave the measure of excretion by the planthoppers. To assess the loss in insect body weight due to catabolism, a control was similarly established, in which the insect was given an access to a moist cotton swab to prevent its desiccation. The amount of food ingested and assimilated was calculated as follows (Khan and Saxena 1984).

$$\text{Food assimilated} = W_1 \times \frac{(C_1 - C_2)}{C_1} + W_2 - W_1$$

Where:

W_1 = initial weight of insect
W_2 = final weight of insect
C_1 = initial weight of control insect
C_2 = final weight of control insect
Food ingested = food assimilated + weight of honeydew

Statistical analyses of the data were performed using suitable transformations (square root) in the completely randomized design (CRD).

RESULTS AND DISCUSSION

The maximum number of eggs were laid by *S. furcifera* females on susceptible variety *TN* 1 (110.75 eggs/5 females) followed by PR 114 which were statistically at par with one another (Table1). The number of eggs laid by hopper females on plants representing moderately resistant and resistant cultivars *viz.* PR 108, PAU 201 and ARC 6248 were 97.75, 91.75 and 90.25 per 5 females, respectively which were statistically at par with each other and PR 114 (100.0 eggs/5 females). The present findings are in line with the findings of Vaidya and Kalode (1981) who reported the rice variety *TN1* to be the most preferred one, for egg laying in contrast to other resistant varieties. Mishra and Misra (1991) observed differential preference of the WBPH for oviposition on different rice varieties and reported that fewer planthopper eggs (9.33-19.17) were deposited on resistant varieties than on the susceptible varieties. However, Rodrigues-Rivera (1972) and Pablo (1977) reported identical response of *S. furcifera* adults to different resistant and susceptible rice cultivars. Saxena and Pathak (1977) also demonstrated that the resistant and susceptible rice cultivars were equally suitable for oviposition by planthopper, *N. lugens.*

The quantity of food ingested and assimilated by *S. furcifera* females was significantly higher on susceptible varieties, *TN1* and PR 114 (Table 1). The quantity of food assimilated on variety *TN1* (5.71 mg) was statistically at par with PR 114. Quantity of food assimilated by hopper females on moderately resistant variety PR 108 (3.56 mg) was significantly lower than that the susceptible varieties, *TN1* and PR 114 but statistically at par with that on PAU 201 (3.46 mg). WBPH females assimilated significantly lower food on both the resistant rice varieties, NCS 2041 (0.46 mg) and ARC 6248 (0.38 mg) than the susceptible and the moderately resistant test varieties. *S. furcifera* females excreted significantly highest amount of honeydew when allowed to feed on *TN1* plants (72.50 mg/5 females) followed by PR 114. Honeydew excreted by female hoppers was significantly lower on moderately resistant varieties, PR 108 and PAU 201 in comparison to susceptible ones. WBPH females excreted least amount of honeydew on resistant variety, NCS 2041 (16.00 mg/5 females) which was significantly lower than that on resistant variety ARC 6248 (21.50 mg/5 females). *S. furcifera* females ingested significantly higher amount of food on *TN1* (78.21 mg) as compared to PR 114, PAU 201, PR 108, ARC 6248) and NCS 2041. The present findings are in agreement with findings of Khan and Saxena (1985) and Velusamy (1989) who reported that the quantity of food assimilated by *S. furcifera* on resistant cultivars was significantly less as compared to susceptible cultivar, *TN1.* Suri and Singh (2009) also reported significantly less feeding and consequently less honeydew excretion by *S. furcifera* on resistant variety, ARC 6248 as compared to the susceptible,

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Table 1. Oviposition and feeding response of *S. furcifera* on different rice varieties

Rice Variety	Eggs laid* (no/5♀)	Initial weight of hoppers# (mg)	Final weight of hoppers# (mg)	Food assimilated# (mg)	Honeydew excreted# (mg)	Food ingested# (mg)
TN 1	110.75(10.57)	10.00	14.00 (3.86)	5.71 (2.59)	72.50 (8.57)	78.21 (8.90)
PR 114	100.00(10.04)	8.50	12.00 (3.61)	4.97 (2.44)	65.50 (8.15)	70.47 (8.45)
PR 108	97.75(9.93)	9.00	11.00 (3.46)	3.56 (2.12)	32.43 (5.78)	35.99 (6.08)
PAU 201	91.75(9.62)	8.50	10.50 (3.39)	3.46 (2.11)	33.50 (5.87)	36.96 (6.16)
NCS 2041	87.75(9.42)	8.50	7.50 (2.91)	0.46 (1.19)	16.00 (4.12)	16.46 (4.17)
ARC 6248	90.25(9.55)	8.00	7.00 (2.83)	0.38 (1.16)	21.50 (4.74)	21.88 (4.78)
C.D. (p=0.05)	(0.53)	NS	(0.31)	(0.31)	(0.30)	(0.29)

*Average of four replications; each comprising of 5 gravid females caged on 30-day-old rice plants;
#Average of three replications; each comprising of 5 females per parafilm sachet;
Figures in parentheses are square root transformations.

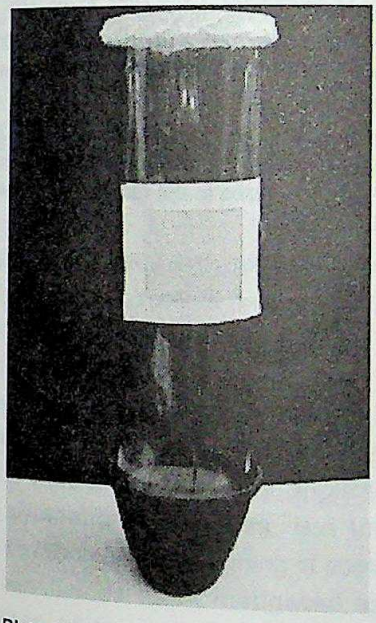


Plate 1. Rice plants in a Mylar film cage

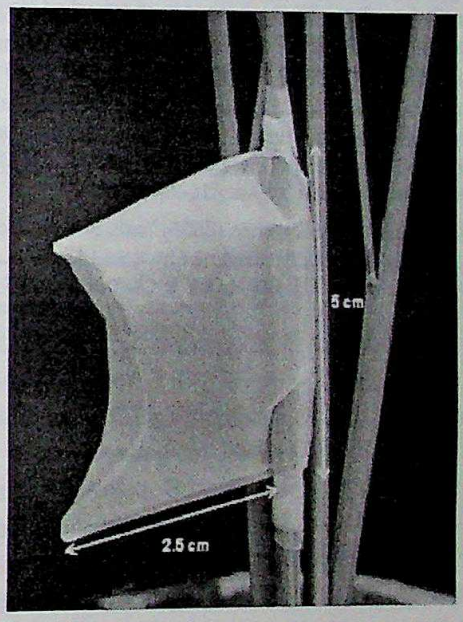


Plate 2. Parafilm sachet for confining *S. furcifera* adults during feeding experiment

PR 116. They attributed lesser feeding of the hopper to the presence of more than two times the amount of total phenols in the leaves of the resistant variety, ARC 6248 in contrast to susceptible variety, PR 116. Earlier, Liu *et al.* (1990) reported significantly less honeydew excretion by *S. furcifera* on resistant varieties as compared to susceptible, *TN1*. Lal and Pathak (1999) also reported significantly less quantity of food ingestion by *S. furcifera* on resistant cultivars than on susceptible, *TN1*.

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Bioefficacy and Economics of Biopesticides and Insecticides against Carnation Bud Borer, *Helicoverpa armigera* (Hubner)

S. Pal*, H. Chatterjee[2] and S.K. Senapati[3]

Regional Research Station, Uttar Banga Krishi Viswavidyalaya, Kalimpong, Darjeeling, West Bengal 734301

[2]Department of Plant Protection, Palli Siksha Bhavana, Visva-Bharati, Sriniketan, Birbhum, West Bengal 731236

[3]Department of Agril. Entomology, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal 736165

**E-mail: palsento@gmail.com*

Abstract: An experiment was carried out at Regional Research Station, Uttar Banga Krishi Viswavidyalaya, Kalimpong, West Bengal during the winter seasons of 2009-10 and 2010-11, to assess the comparative efficacy and economics of biopesticides as well as some new eco-friendly molecules against *Helicoverpa armigera* in comparison to conventional insecticide. The chemical insecticides particularly the newer molecules indoxacarb and flubendiamide were superior to biopesticides like *Bacillus thuringiensis*, neem seed powder extract and nuclear polyhedrosis virus in reducing the infestation of carnation bud borer, *Helicoverpa armigera* and providing higher net return per rupee invested. The treatments with combination of half dose of endosulfan with NPV and neem seed powder extract recorded moderate level of effectiveness against *H. armigera* but were superior to individual treatments with biopesticides in efficacy and economics.

Key words: Carnation bud borer, biopesticides, insecticides, bioefficacy, economics

Carnation, *Dianthus caryophyllus* Linnaeus, family caryophyllaceae is an excellent ornamental plant and ranks amongst the top ten cut flowers of the world. The bud borer, *Helicoverpa armigera* (Hubner) is the most important pest of this plant causing serious damage to the buds and flowers (Sood, 1988; Multani and Sohi, 2002). Traditionally this pest is controlled mainly by application of broad spectrum synthetic insecticides. But the problem of resistance development and banning of some conventional harmful insecticides have instigated to explore the effectiveness of bio-pesticides and new molecule insecticides for the management of this pest. Biopesticides like Bt, Ha NPV, Dipel and NSKE were found as effective as endosulfan against *Helicoverpa armigera* (Prasad *et al.*, 2003). Sharma (2004) reported that biopesticides applied in combination with the synthetic insecticides or in rotation were quite effective for the management of this pest. Amongst new insecticides the indoxacarb and flubendiamide were found highly effective against *Helicoverpa armigera* and can be used successfully in insecticide resistance management programme (Dhawan and Gill, 2005; Lakshminarayana and Rajarshri, 2006; Gill *et al.*, 2010). Therefore, the present investigation was undertaken to assess the comparative efficacy and economics of biopesticides including neem as well as some new eco-friendly molecules against *Helicoverpa armigera* in comparison to conventional insecticide.

MATERIAL AND METHODS

The experiment was carried out in the naturally ventilated low cost polyhouse at the farm of Regional Research Station (Hill Zone), Uttar Banga Krishi Viswavidyalaya, Kalimpong, Darjeeling, West Bengal, India during winter seasons of 2009-10 and 2010-11. Rotted cuttings of the variety 'Sunrise' were planted in 2 X 1 meter plots at a spacing of 25 X 25 cm following normal agronomical practices. The experiment was laid out in randomized block design (RBD) with nine treatments and three replications. The treatments were as follows: T_1 - Endosulfan @1.5ml/lit; T_2 – Indoxacarb@0.3ml/lit; T_3 – Flubendiamide@0.1ml/lit; T_4 – *Bacillus thuringiensis* var. *kurstaki* (Btk) @1g/lit; T_5 – Neem seed powder extract (NSPE) @40g/lit; T_6 - Nuclear polyhedrosis virus (NPV) @1.5ml/lit; T_7 – NPV+Endosulfan (1.5ml + 0.75ml/lit); T_8 – NSPE+Endosulfan; (40g + 0.75ml/lit), T_9 - Control (water spray)

The treatments were applied twice at an interval of 21 days as foliar spray with the help of a knapsack sprayer with a spray fluid volume of 1000 litre/ha. The spraying operation was initiated when appreciable number of adult moths started appearing in the pheromone traps. The pre treatment counts on total number of buds and number of infested buds were recorded from ten plants per plot selected at random to calculate the data on per cent bud borer infestation. Similarly the post treatment observations

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were recorded 1, 3, 7 and 14 days after spraying. The data thus recorded were subjected to angular transformation and then analyzed using OPSTAT statistical package. The treatment means were compared with Least Significant Difference (LSD) at 5 % level. The observations on healthy marketable flower yield/plot were recorded after 14 days of each round of spraying. The data were pooled for statistical analysis. The economics of different pesticidal treatments was calculated on the basis of prevailing price of carnation flower stick at the farm level, pesticides and labour charges for pesticidal application. Net gain/rupee invested in different pesticidal treatments was calculated by dividing the net income with cost of protection for each treatment.

RESULTS AND DISCUSSION

During 2009-10, the percent bud infestation caused by *H. armigera* in carnation did not differ before spray in case of first application of insecticides. After three days of spray, the percent bud infestation was significantly lower in indoxacarb and flubendiamide (9.65 and 10.28%) being at par with all other treatments except NPV + endosulfan (Table1). However all the treatments were better than control. After 7 days of spray, the percent bud infestation was lowest in indoxacarb and flubendiamide (5.85 and 6.48%) as compared to all other treatments. Indoxacarb and flubendiamide (6.51 and 6.70%) were again found to be most effective after 14 days of spray which was at par with Btk (7.58%).

After the second spray the percent bud infestation was significantly lower in indoxacarb, flubendiamide and NPV + endosulfan (5.64, 6.55 and 7.27 %, respectively) in comparison to all other treatments after 3 days of spray (Table1). After 7 days of spray, almost similar trend was recorded. The significantly lower infestation was recorded with indoxacarb, flubendiamide, NPV + endosulfan and NSPE +endosulfan (4.62, 5.33, 4.89 and 5.28 %, respectively) after 14 days of spray. All the treatments were better than control.

During 2010-11, the percent bud infestation caused by *H. armigera* in carnation did not differ before spray in case of first application of insecticides. After three days of spray, the percent bud infestation was significantly lower in indoxacarb, flubendiamide (7.10 and 7.29%) being at par with endosulfan, NSPE, NPV + endosulfan and NSPE + endosulfan (8.33, 9.60, 9.17 and 9.33, respectively) (Table2). After 7 days of spray, the percent bud infestation was lowest in flubendiamide, indoxacarb, endosulfan, NPV+ endosulfan and NSPE + endosulfan as compared to all other treatments. The lowest bud infestation was recorded in indoxacarb and flubendiamide (5.14 and 6.54%) which was at par with endosulfan, NPV + endosulfan and NSPE + endosulfan (6.72, 6.44 and 7.19%, respectively)

After the second spray the percent bud infestation was significantly lower in indoxacarb, and flubendiamide (3.69 and 4.43%) which was at par with endosulfan and NPV + endosulfan as compared to all other treatments after 3 days of spray (Table2). After 7 days of spray, almost similar trend was recorded. The significantly lower infestation was recorded with indoxcarb, flubendiamide (3.27 and 3.46%), which was at par with NPV + endosulfan, NSPE +endosulfan, endosulfan, and NPV (4.06, 4.24, 4.41and 4.43 %, respectively) after 14 days of spray. All the treatments were better than control.

During 2009-10, the highest marketable flower yield per plot was obtained with Indoxacarb (10.33) which was at par with flubendiamide (10.17) and NPV + endosulfan (9.67) (Table 3). The highest net gain/rupee invested was obtained for indoxacarb (Rs. 13.19) followed by endosulfan (Rs. 8.60) and flubendiamide (Rs. 7.97). During 2010-11, the application of indoxacarb and flubendiamide resulted in the production of higher number of marketable flowers per plot (9.83 and 9.67) which was at par with NPV + endosulfan (9.17), NSPE + endosulfan (8.50) and endosulfan (8.50). The application of indoxacarb recorded the highest net gain/ rupee invested i.e. Rs. 14.50 followed by endosulfan (Rs. 10.87) and flubendiamide (Rs. 8.85).

Therefore, the newer molecules indoxacarb and flubendiamide were superior in reducing the incidence of carnation bud borer and proving higher monetary returns. These results are in agreement with the findings of Gunning and Devonshire (2003) and Hewa *et al.* (2003) who reported that indoxacarb had significantly better efficacy against *Helicoverpa armigera* and is potentially suitable for its inclusion in integrated pest management. The effectiveness of flubendiamide against *H. armigera* has earlier been reported by Lakshminarayana and Rajashri (2006) and Tatagar *et al.* (2009). However, the combination of half dose of endosulfan with NPV and neem seed powder extract recorded moderate level of effectiveness against bud borer and provided comparatively better economy than the solitary application of biopesticides. These observations draw adequate support from the findings of earlier workers like Bijjur *et al.* (1994), Katole *et al.* (2000), Mandal and Mishra (2003) and Thakre *et al.* (2003) who reported that biopesticides applied in combination with the synthetic insecticides or in rotation are quite effective for *Helicoverpa* control on different crops. The lower net gain/rupee invested for biopesticides could be attributed to comparatively less efficacy as well as higher cost of biopesticides thereby increasing the cost of pesticidal application. However,

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Table 1. *Bioefficacy of biopesticides and inse cticides against carnation bud borer, Helicoverpa armigera* (Hb.) during 2009-10.

Treatments	Bud borer infestation (%)									
	Pre treatment	Days after first spraying				Pre treatment	Days after second spraying			
	(1 DBS)	1	3	7	14	(1 DBS)	1	3	7	14
T_1-Endosulfan @1.5ml/lit	16.40	12.74	11.48ab	9.47b	8.67bc	11.72bc	9.58ab	7.59b	5.63b	6.10ab
	(23.86)*	(20.90)	(19.75)	(17.91)	(17.10)	(20.00)	(18.01)	(15.97)	(13.66)	(14.19)
T_2– Indoxacarb@0.3ml/lit	15.79	12.22	9.65a	5.85a	6.51a	9.30a	7.61a	5.64a	3.59a	4.62a
	(23.40)	(20.44)	(18.07)	(13.88)	(14.75)	(17.74)	(16.00)	(13.69)	(10.92)	(12.28)
T_3– Flubendiamide@0.1ml/lit	17.03	11.87	10.28a	6.48a	6.70a	10.21ab	7.78a	6.55ab	4.57ab	5.33a
	(24.35)	(20.13)	(18.44)	(14.74)	(14.99)	(18.62)	(16.12)	(14.80)	(12.31)	(13.27)
T_4– Btk@1g/lit	16.62	13.90	12.98abc	9.85b	7.58abc	11.29abc	10.19ab	7.84b	6.49bc	5.83ab
	(23.90)	(21.83)	(21.11)	(18.25)	(15.95)	(19.56)	(18.52)	(16.24)	(14.74)	(13.95)
T_5– NSPE@40g/lit	15.10	14.07	11.76ab	9.74b	10.00c	12.65bc	10.18ab	9.03b	7.84c	8.11b
	(22.85)	(21.98)	(20.02)	(18.12)	(18.33)	(20.80)	(18.58)	(17.45)	(16.24)	(16.51)
T_6- NPV@1.5ml/lit	16.65	14.33	12.40ab	11.98b	9.51bc	12.63c	10.66b	8.12b	6.39bc	6.00ab
	(24.01)	(22.22)	(20.61)	(20.21)	(17.92)	(20.79)	(19.05)	(16.52)	(14.50)	(14.15)
T_7– NPV+Endosulfan	16.47	13.59	11.57bc	9.28b	8.74bc	11.99bc	9.20a	7.27ab	4.77ab	4.89a
(1.5ml + 0.75ml/lit)	(23.81)	(21.58)	(22.58)	(17.72)	(17.18)	(20.19)	(17.65)	(15.61)	(12.58)	(12.64)
T_8– NSPE+Endosulfan	16.31	12.83	11.06ab	9.14b	9.10bc	12.91c	9.08ab	7.58b	5.12ab	5.28a
(40g + 0.75ml/lit)	(23.63)	(20.93)	(19.40)	(17.56)	(17.46)	(21.02)	(17.47)	(15.93)	(12.97)	(13.20)
T_9 - Control	17.73	17.38	16.62c	17.00c	16.82d	16.12d	16.15c	15.15c	14.44d	13.48c
	(24.87)	(24.62)	(24.03)	(24.34)	(24.20)	(23.64)	(23.62)	(22.90)	(22.31)	(21.52)
C.D. (P=0.05)	NS	NS	(3.53)	(2.51)	(2.68)	(2.04)	(2.77)	(2.00)	(2.51)	(3.03)

DBS – Day before spraying

* Figures in parentheses are angular transformed values

Figures in the same column indicated by same alphabet are not statistically different; Btk: *Bacillus thuringiensis* var. *kurstaki*, NSPE: Neem seed powder extract; NPV: Nuclear polyhedrosis virus

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Table 2. Bioefficacy of biopesticides and insecticides against carnation bud borer, *Helicoverpa armigera* (Hb.) during 2010-11.

Treatments	Bud borer infestation (%)									
	Pre treatment	Days after first spraying				Pre treatment	Days after second spraying			
	(1 DBS)	1	3	7	14	(1 DBS)	1	3	7	14
T_1-Endosulfan @1.5ml/lit	12.15	10.80	8.33ab	6.33ab	6.72ab	9.26a	7.47bc	5.37abc	4.17abx	4.41ab
	(20.37)*	(19.15)	(16.69)	(14.57)	(14.88)	(17.70)	(15.84)	(13.34)	(13.34)	(12.06)
T_2– Indoxacarb@0.3ml/lit	12.39	10.07	7.10a	5.11ab	5.14a	7.72a	5.21a	3.69a	2.71a	3.27a
	(20.60)	(18.49)	(15.41)	(12.99)	(13.02)	(16.07)	(13.12)	(11.06)	(7.73)	(8.52)
T_3– Flubendiamide@0.1ml/lit	12.86	10.39	7.29a	4.73a	6.54a	8.36a	6.00ab	4.43ab	3.14ab	3.46ab
	(20.96)	(18.76)	(15.64)	(12.46)	(14.77)	(16.78)	(14.17)	(12.08)	(8.34)	(10.71)
T_4– Btk@1g/lit	12.33	11.14	10.68bc	8.42b	8.15b	9.71b	8.71c	7.52c	5.78b	4.74ab
	(20.52)	(19.42)	(19.05)	(16.70)	(16.52)	(18.14)	(17.15)	(15.86)	(13.90)	(12.52)
T_5– NSPE@40g/lit	12.39	10.92	9.60ab	8.31b	8.87b	9.77b	7.42bc	6.59bc	6.34b	6.27b
	(20.52)	(19.25)	(18.00)	(16.73)	(17.31)	(18.20)	(15.72)	(14.83)	(14.56)	(14.44)
T_6- NPV@1.5ml/lit	13.12	11.32	10.55bc	8.17b	8.04b	7.55a	7.16bc	6.23bc	5.16ab	4.43ab
	(21.13)	(19.61)	(18.89)	(16.40)	(16.25)	(15.92)	(15.51)	(14.21)	(13.09)	(12.10)
T_7– NPV+Endosulfan	11.96	10.88	9.17ab	7.13ab	6.44ab	8.73a	7.01abc	4.48ab	3.77ab	4.06ab
(1.5ml + 0.75ml/lit)	(20.22)	(19.22)	(17.61)	(15.42)	(14.64)	(17.17)	(15.27)	(12.16)	(11.18)	(11.61)
T_8– NSPE+Endosulfan	13.21	11.21	9.33ab	7.75ab	7.19ab	9.73b	7.76bc	6.33bc	4.93ab	4.24ab
(40g + 0.75ml/lit)	(21.30)	(19.55)	(17.70)	(16.04)	(15.49)	(18.15)	(16.11)	(14.55)	(12.78)	(11.87)
T_9- Control	12.24	13.51	13.70c	14.57c	15.86c	14.37c	15.41d	13.55d	14.99c	13.45c
	(20.41)	(21.55)	(21.65)	(22.42)	(23.46)	(22.26)	(23.07)	(21.57)	(22.70)	(21.49)
C.D. (P=0.05)	NS	NS	(2.94)	(3.66)	(2.62)	(1.84)	(2.31)	(3.08)	(6.12)	(4.69)

DBS – Day before spraying

* Figures in parentheses are angular transformed values

Figures in the same column indicated by same alphabet are not statistically different

Table 3. *Economics of biopesticides and insecticides against carnation bud borer, Helicoverpa armigera* (Hb.)

	Marketable	*Marketable*	*Additional flower*	*Additional income*	Cost of	Net income	Net gain

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Table 3. Economics of biopesticides and insecticides against carnation bud borer, Helicoverpa armigera (Hb.)

Treatments	Marketable flower (No./Plot)		Marketable flower (No./100 sq.m.)		Additional flower over control (No./100 sq.m.)		Additional income over control (Rs. /100 sq.m.)		Cost of protection (Rs. /100 sq.m.)		Net income (Rs. /100 sq.m.)		Net gain (Rs.)/rupee invested	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1 -Endosulfan @1.5ml/lit	8.83c	8.50ab	441.50	425.00	108.00	133.50	108.00	133.50	11.25	11.25	96.75	122.25	8.60	10.87
T_2 – Indoxacarb@0.3ml/lit	10.33a	9.83a	516.50	491.50	183.00	200.00	183.00	200.00	12.90	12.90	170.10	187.10	13.19	14.50
T_3 – Flubendiamide@0.1ml/lit	10.17ab	9.67a	508.50	483.50	175.00	192.00	175.00	192.00	19.50	19.50	155.50	172.50	7.97	8.85
T_4 – Btk@1g/lit	8.50cd	6.83bc	425.00	341.50	91.50	50.00	91.50	50.00	16.02	16.02	75.48	33.98	4.71	2.12
T_5 – NSPE@40g/lit	7.50de	7.17bc	375.00	358.50	41.50	67.00	41.50	67.00	14.50	14.50	27.00	52.50	1.86	3.62
T_6 - NPV@1.5ml/lit	8.33cd	7.00bc	416.50	350.00	83.00	58.50	83.00	58.50	40.50	40.50	42.50	18.00	1.05	0.44
T_7 – NPV+Endosulfan (@1.5ml + 0.75ml/lit)	9.67abc	9.17a	483.50	458.50	150.00	167.00	150.00	167.00	43.88	43.88	106.12	123.12	2.42	2.81
T_8 – NSPE+Endosulfan (@ 40g + 0.75ml/lit)	9.00bc	8.50ab	450.00	425.00	116.50	133.50	116.50	133.50	17.88	17.88	98.62	115.62	5.52	6.47
T_9 - Control	6.67e	5.83c	333.50	291.50	-	-	-	-	-	-	-	-	-	-
C.D. (P=0.05)	1.24	1.80												

Figures in the same column indicated by same alphabet are not statistically different; Price of carnation flower at the farm level: Rs. 1/flower
Cost of biopesticides and insecticides: Endosulfan (Thiodan 35 EC) @ Rs. 45/100 ml, Indoxacarb (Avaunt 14.5 SC) @ Rs. 280/100 ml, Flubendiamide(Fame 480 SC) @ Rs. 150/10 ml, *Bacillus thuringiensis* var. *kurstaki* (Halt 5 % WP) @ Rs. 1152/kg, Neem fruit powder (Agri Life) @ Rs. 25/kg, NPV (Heli-cide) @ Rs. 240/100 ml
Labour charges for insecticidal application: Rs. 450/spray/ha

keeping the safety to environment in view, to overcome the developing insecticidal resistance problem and to reduce over-reliance on insecticidal usage, mixture of biopesticides and synthetic insecticides may be used for the management of carnation bud borer. Here it is worth mentioning that at the time of commencement of this investigation endosulfan was not banned. But now as this insecticide has been banned it should be replaced by other synthetic chemical. In view of the higher monetary returns from indoxacarb and flubendiamide, these insecticides may also be used against the bud borer and should be used alternatively to avoid development of resistance to these insecticides.

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Infestation of *Chilo partellus* (lepidoptera) Larvae in Cultivated and Wild Graminaceous Host Plants

C.B. Tiwary[1]*, Jawaid Iquabal[2], C.M. Pandey[3] and Kumari Chanda[3]

[1]*SMD College, MN Jalalpur Gopalganj (Bihar)*
[2]*PG Dept. of Zoology, Z.A. Islamia College, Siwan (Bihar)*
[3]*Jay Prakash University, Chapra (Bihar)*
**E-mail: tiwary_cb@rediffmail.com*

Abstract: Host plant choice of first instar larvae *Chilo partellus* was evaluated for graminaceous plants in no choice, two-choice and multiple-choice tests under laboratory conditions. The host plants were *Trifolium alexandrinum* (*barseem*), *Hardeum vulgare* (*barley*), maize, sorghum, sugarcane and *Pennisetum glaucum* (Pearl millet). Under no-choice conditions, higher number of larvae were observed on *T. alaxandricum* than on maize and were in contrast with the results obtained in two and multiple choice test where fewer larvae were observed on maize. A similar pattern was observed between *T. alaxandricum* and Pearl millet. Similar numbers of larvae settled on sugarcane, maize and pearl millet. These results indicate poor acceptance of wild grass by *C. partellus* larvae. Larvae were biased towards maize after one hour and 24 hours of infestation. This study related to insect response triggered by graminaceous grasses is important for the control of first instar larvae under field conditions. Therefore, non-suitable grasses such as *T. alaxandricum* can play an important role in reducing establishment of first instar larvae in adjacent crop plants like maize in a habitat management system.

Key Words: *Chilo partellus*, larval preference, host plants, habitat management

Maize (*Zea mays* L.) is extensively grown for food grains, feed and fodder purposes and is cultivated in an area of 70 lakh hectares with a production of 140 lakh metric tonnes in India. The average yield of the crop in India is 20.0 quintal per hectare, which is very low as compared to average yield of 49.06 quintal per hectare in the world. A number of insects cause minor to serious damage to maize crop. Sarup *et al* (1987) listed 130 such insect species. However, the total number of insect and mite pests exceeds 250 (Mathur, 1991). The insects namely *Chilo partellus* (Swinhoe), *Sesamia inferens* (Walker) and *Atherigona naqvii* (Steyskal) and *A. soccata* (Rondani) have been recorded as most serious pests of this crop and wide spread in India causing substantial reduction in crop yield. Amongst the most serious pests is the *Chilo partellus* (Lepidoptera: Crambidae). The eggs were laid by *C. partellus* on the substrate of their choice on a particular plant. After hatching when the larvae oriented towards a suitable host plant it would remain settled and feed. However, the presence of chemical and/or morphological factors may influence larval orientation, settling and feeding response (Khan, 1997). The host specificity testing of many insects was a combination of choice and no-choice tests and knowledge about key behavioural concepts can assist in the interpretation of these differences. Insects use a variety of behaviours to ensure that they remain in the presence of host plants and choice tests can predict the host range of most particular insects most of the time. However, insects can find themselves in situations where the target weed is not present or is encountered so infrequently that insects become responsible to lower ranked hosts. Insects may accept a wider number of plants as hosts under these conditions. No-choice tests provide us with the best tool to predict the outcome of this situation. Sometimes insects cannot locate host plants and lead to oviposition on less preferred hosts. Again, no-choice tests will predict the propensity to accept lower ranked hosts under these circumstances. Choice tests are often used to measure orientation and setting response with selection of a suitable site in which the larvae have an option of whether to accept the plant or not (Smith *et. al.,* 1994). No-choice tests have been used to determine the levels of larval antibiosis in maize hybrids (Davis *et. al.,* 1989), fodder grasses (Wiseman *et. al.,* 1982) and the extent of damage. The use of no-choice combination with choice-test can be of importance in confirming the presence of resistance in a wide variety of plants. The first instar larvae of *C. partellus* showed less feeding behaviour on resistant sorghum (*Sorghum bicolor*) cultivars due to high concentration of hydrogen cyanide (HCN) in the plants. This behavioural response could be used as a tool for the control of stem borers. The objectives of the study were to determine insect larvae response to leaf discs of single cultivated and wild host plant with no-choice test, preference of larvae for leaf discs of two different host plants with two-choice test and the larval preference for leaf discs of more than two host plants (cultivated and wild) with multiple-choice test.

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MATERIAL AND METHODS

Larval behaviour to host plants was determined by using no-choice test in the laboratory. Leaf discs (1.2 cm diameter) were discarded from host plants placed in the centre of a petridish lined with 0.5 cm agar as nutrient. The experiment was repeated six times with eight replicates each time for each host plant. Ten neonate larvae were placed on the leaf disc of each host plant in the petridishes using a camel hairbrush. Thereafter, the dishes were sealed with transparent gladrap plastic to prevent the escaping larvae. In the plastic small holes were made to ensure air circulation and prevent the build up of moisture inside petridishes. Petri dishes were placed in the dark at a constant temperature of 260C to prevent the effect of light on the movement of neonate larvae due to positive phototaxis. The number of larvae was counted on and below the leaf disc of each host plant after 1, 4 and 24 hours after infestation to determine host plant preferences.

The experiment was conducted by two-choice test under similar conditions as in case of no-choice test. The following combinations of plant species were evaluated: maize vs *T. alaxandricum*, maize vs *H. vulgare*; pearl millet vs *T. alaxandricum* and *H. vulgare*; sugarcane vs *T. alaxandricum* and *H. vulgare* and Sorghum vs *T. alaxandricum* and *H. vulgar,* respectively. The experiment was repeated six times with eight replications. Leaf discs of the two host plants were placed at opposite ends along the edge of a petridish (9 cm diameter). The number of larvae on each leaf disc were recorded at one, four, and 24 hours after inoculation. The experiment was also conducted under multiple-choice test similar to no-choice and two-choice tests using the same six host plants. One leaf disc was used for each host plant. Leaf discs of all species were placed at equal distance from each other along the edge of each petridish with 15 cm diameter. The experiment was repeated six times with six replications for each time. Thirty neonates were carefully placed in the centre of each petridish. The number of larvae on different leaf discs were recorded at intervals of one, four and 24 hours after infestation. Analysis of variance was used in no-choice and multiple-choice tests to determine if there were significant differences in mean number of larvae on leaf discs among host plants. In two-choice tests, t-tests were used to determine differences between mean number of larvae per plant.

RESULTS AND DISCUSSION

No-choice test: Significant differences were observed in the number of larvae on leaf discs of the host plants after one (F=17.86, d. f. = 42, P=0.0001) and four hours (F= 16.44, d. f. = 42, P= 0.0001) as shown in Table 1. More larvae were recorded on sugarcane and *T. alaxandricum* than other host plants, although the differences were non-significant. Similar numbers of larvae settled on sugarcane, maize and pearl millet. The number of larvae on *H. vulgare* was significantly lower than recovered on any other host plant. Significant differences (F= 15.68, d. f.= 42, P= 0.0001) were again observed between the number of larvae on cultivated and wild host plants after 24 hours infestation, significantly more larvae were recorded on sugarcane followed by *T. alaxandricum*, maize, sorghum and pearl millet. Only fewer larvae were again recorded on *H. vulgare* than on any other host plant.

Two-choice test: Significantly fewer larvae were recovered on leaf discs of *H. vulgare* when compared to maize (One hour: F=10.92,d.f. = 14, P= 0.0052; four hours: F=7.45,d.f.=14, P= 0.0001 and 24 hours: F= 5042, d. f.=14,P=0.0001), sorghum (One hour: F= 5.21,d.f.= 14,P= 0.0386; four hours: F= 6.09,d.f.= 14, P= 0.0013), sugarcane (One hour: F= 58.65, d. f.= 14, P=0.001; four hours: F= 45.04, d. f.= 14, P=0.0001; 24 hours: F= 11.99, d. f.=14, P=0.0001) and pearl millet (One hour: F= 17.99, d. f.= 14, P= 0.0254 and four hours: F= 5.11, d. f.= 14, P= 0.0402) as shown in Table 2. Number of larvae between *H. vulgare* and pearl millet were not significantly different (F=1.69, d. f. = 14, P=0.2146) after 24 hours inoculation. No significant differences (One hour: F=0.078, d. f. = 14, P= 0.7845; Four hours: F= 0.19 d.f.-14, P=0.6737 and 24 hours: F= 2.61, d. f.

Table 1. Mean number of *Chilo partellus* larvae left per leaf disc in no-choice tests after one, four and 24 hours inoculation (±S.D.)

Host plant	1 hour	4 hour	24 hour
H. vulgare	3.83±0.8ba	3.44±1.16a	2.25±0.62a
Pearl millet	5.58±1.00b	5.19±0.80b	4.31±0.67bc
Maize	5.98±1.05b	5.90±1.09b	4.84±1.03c
Sugarcane	6.06±0.50bc	6.00±1.00b	3.71±1.08b
T. alaxandricum	6.88±0.87d	6.83±1.27c	5.11±1.03c
Sorghum	7.65±0.87d	7.73±0.70c	6.41±1.38d

Means within each column followed by a different letter are significantly different (P<0.05).
Number of larvae per host plant=10 larvae.

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= 14, P=0.1284) were observed in larval settling and was significantly higher on *T. alaxandricum* than on sugarcane only at 24 hours (F= 6.07, d. f.= 14, P= 0.0273) after inoculation. No significant differences (One hour: F= 0.03, d. f. = 14, P=0.8668; four hours F= 0.01, d. f. = 14, P=0.9258 and 24 hours: F= 0.27, d. f. = 14 P=0.6147) were observed in larvae settling on pearl millet Vs *T. alaxandricum* (Table 2).

Multiple-choice test: No significant differences were observed in number of larvae on leaf discs of host plants after one (F= 1.31, d. f. =30, P= 0.2858) and four hour (F= 0.84, d. f. = 30, P=0.5301) infestation (Table 3). However, significant difference were observed after 24 hours of infestation (F=2.89, d. f. =30, P=0.0304) in the number of larvae on leaf discs of host plants. Although *H. vulgare* and *T. alaxandricum* had most, followed by sugarcane and pearl millet with non-significant differences. The result of no-choice tests with higher number of larvae observed on *T. alaxandricum* than on maize were in contrast with the results obtained in two and multiple choice test with fewer larvae were observed on maize. A similar pattern was observed between *T. alaxandricum* and Pearl millet. Smith *et al* (1994) reported possible differences in insect behavioural response in choice and no-choice tests. The results of no-choice tests may possible indicated that in the absence of suitable host plants, first instar larvae are likely to settle on *T. alaxandricum* for a while. Therefore, if larvae could stay longer than 24 hours on *T. alaxandricum* this could possibly bring an added advantage to insect pest management. *C. partellus* larvae that fed on *T. alaxandricum* did not survive (Khan *et al.*, 2000) Furthermore, this grass exhibited hairs on leaf, which may interfere with larval feeding (Bernays and Chapman, 1994). The higher number of larvae on leaf discs of maize than on *T. alaxandricum* indicated high performance for maize under choice conditions.

Chapman *et al.* (1983) observed that most first instar *C. partellus* larvae climbed off a plant within the first 24 hours after hatching. Under same field conditions, larval antixenosis on grasses such as *H. vulgare* and *T. alaxandricum* is likely to result in high mortality of first instar larvae. The insect must first locate and remain on a plant before it can feed and become established (Berger, 1994). Therefore, the period between eclosion of eggs and larval establishment of *C. partellus* larvae at the feeding site appear to be critical stage in the colonization process (Ampofo, 1986) due to larval dependence on limited energy resources. During this period, plants quality, which slows down larval movement or cause larvae to leave the plant (Berger, 1994), exposes them for longer period to predators, dehydration and other harsh environmental conditions (Chapman *et al.*, 1983). Ross and Ostile (1990) reported mortality of migrating first instar larvae of European corn borer, *Ostrinia nubilalis* (Lepidoptera: Pyralidae) to be between 76 and 83 per cent and mortality occurring mainly within the first 48 hours after egg hatching. High number of larvae climbed off the leaf discs of *H. vulgare* than on other

Table 2. Mean number of *Chilo partellus* larvae found per plant leaf disc in two choice tests after one, four and 24 hours inoculation (mean±S.D.)

Host Plant Combinations	1 hour	4 hour	24 hour
*H. vulgare*Pearl millet	2.15±0.58a	2.38±0.66a	3.00±0.58a
	2.94±0.68b	3.21±0.80b	2.56±0.76a
*Trifolium alaxandricum*Pearl millet	4.11±0.80a	3.89±1.15a	4.22±1.10a
	4.19±1.06a	3.83±1.27a	4.50±1.50a
*H. vulgare*Maize	1.96±0.41a	2.58±0.72a	1.75±0.60a
	3.66±1.39b	2.83±0.96a	5.06±1.78b
*Trifolium alaxandricum*Maize	2.55±0.53a	2.64±0.77a	2.73±0.56a
	2.35±0.8aa	2.83±0.96a	3.73±1.6ba
*H. Vulgare*Sorghum	2.10±0.69a	3.12±0.70a	3.46±1.36a
	2.98±0.83b	4.71±1.68b	5.79±0.92b
*Trifolium alaxandricum*Sorghum	4.19±1.07a	6.00±1.07a	6.69±0.86a
	4.26±0.95a	5.22±1.18a	4.83±1.20b
*H. vulgare*Sugarcane	1.77±0.70a	2.29±0.68a	2.46±0.97[a]
	4.31±0.62b	4.87±0.85b	4.94±1.34b
Trifolium alaxandricum Sugarcane	3.52±0.90a	3.88±1.00a	3.83±0.74b
	2.79±0.61b	3.46±0.40a	3.04±0.53a

Means within each column for each two choice test followed by a different letter are Significantly different (P>0.05).
Number of larvae per host plant=20 larvae.

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Table 3. Mean number of *Chilo partellus* larvae per plant in multiple choice tests after one four and 24 hours inoculation.

Host plant	1 hour	4 hour	24 hour
H. vulgare	1.06±0.51a	1.28±0.54a	1.00±0.59a
T. Alaxandricum	1.17±0.26a	1.19±0.46a	1.42±0.23ab
Pearl millet	1.31±0.44a	1.75±0.74a	1.53±0.65ab
Sugarcane	0.83±0.39a	1.25±0.74a	1.75±0.57ab
Sorghum	1.14±0.55a	1.50±0.52a	1.92±0.25b
Maize	1.42±0.38a	1.58±0.43a	1.94±0.63b

Means in each column followed by a different letters are significantly different (P<0.05).
Number of larvae per host plant=30 larvae

host plants under no-choice conditions. Lack of differences in insects behavioural response in no choice and choice tests, where *H. vulgare* were compared to other host plants confirm poor acceptance of this grass by *C. partellus* larvae. Berger (1992) reported movement of newly hatched larvae from one site to another might be influenced by larval density and host plant species. Since only a small number of larvae were used, the possible competition factor between larvae from large egg batches, which may have had an influence on the larval dispersal (Berger, 1992) was excluded in this study. Therefore, the difference between the numbers of first instar larvae that remain settled on leaf discs among host plant may be attributed to morphological and chemical characters at the feeding site. *C. partellus* larvae less preferred *H. vulgare* with smooth surface for feeding due to chemical compound on leaf discs (Bernays and Chapman, 1994). The establishment of neonate *C. partellus* larvae on sorghum might be helped by leaf surface wax and upon resistant plants, neonate larvae spend more time walking and less time palpating eventually leaving without feeding. Chemical characteristics as an important factor in host plant section may affect the recruitment of insects on a plant (Bernays and Chapman, 1994).

Davis *et al.* (1989) did choice tests under laboratory conditions revealed high preference by Corn borers (*Diatraea grandiosella* and *O. nubilalis*) for susceptible maize hybrids to resistant ones. Robinson *et al.*, (1978) revealed greater dispersal of first instar larvae *D. nulilalis* from resistant maize lines than from susceptible lines. These differences were ascribed to high content of 4 benzoxazin-3 (4H)-one (DIMBOA) in resistant maize lines. Wiseman *et al* (1982) evaluated preference of first instars of fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) for excised leaf section of centipede grass (*Eremochola ophiuroides*) Bermuda grass (*Cynodon dactylon*) and carpet grass (*Axonopus affinis*). These studies revealed that first instars of fall armyworm preferred carpet grass or Bermuda grass over the resistant centipedegrass. Ampofo (1986) through field studies showed that the first instar *C. partellus* larvae dispersed from resistant ICZ2-CM maize to a more susceptible cultivar. Significantly, more larvae of fall armyworm *S. frugiperda* crawled off the resistant maize (Antigna 2D-118) to surrounding uninfected plants than susceptible variety (Wiseman *et al.*, 1982). These results illustrate the ability of first instar *C. partellus* larvae to determine differences in acceptability between suitable and non-suitable host plants. Female moths are known to lay their eggs on a suitable host plant for larval development. However, female do not select an appropriate host (Bernays and champ, 1994) and it may have probable reasons for rejection of plants with oviposited eggs by newly hatched larvae. This research showed low leaf damage on the grass compared to the cultivated crops and some first instar larvae might have left the grasses due to larval antixenosis at the feeding site. Since larval migration of a plant could be considered as a mortality factor (Robinson *et al.*, 1978), the practical implications of this behaviour could have some added advantage for pest management in a particular area. It could be practised that first instar larvae that either settle or climb off a trap crop grown around maize or sugarcane field would die without establishing on the main crop. *H. vulgare* was less preferred by first instar larvae compared to other host plants. Knowledge of insects responses triggered by these grasses is important in the control of first instar larvae under field conditions. Therefore, non-suitable grasses such as *T. alaxandricum* can play an important role in reducing larval establishment of first instar larvae in adjacent crop plants such as maize.

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Economic Impact of Dissemination of Integrated Pest Management Technology in Cauliflower in Punjab

Vijay Kumar*, A.K. Dhawan, Ravinder Singh Chandi, H.S. Bhullar and Rajinder Singh

Department of Entomology
Punjab Agricultural University, Ludhiana-141004, Punjab, India
**E-mail: vijay_ento@pau.edu*

Abstract: Integrated pest management (IPM) module developed for insect-pests of cauliflower was implemented in three districts of Punjab during 2009 and 2010. The impact of adoption of IPM strategies resulted in reduction in number of insecticide sprays in IPM villages (4.17 & 3.97) over non-IPM villages (7.33 & 7.50) in both the years. The mean population of diamondback moth was low in IPM villages (1.69 & 2.00 larvae/ plant) as compared to non-IPM villages (10.73 & 9.42 larvae/ plant) in both the years. The mean population of tobacco caterpillar (3.58 and 3.82 larvae/ plant) and cabbage butterfly (2.42 and 2.03 larvae/ plant) was also low in IPM villages as compared to non IPM villages. The average cost of sprays in IPM villages was Rs/ha 4656 and 4641, whereas it was Rs/ha 9387 and 9191 in non-IPM villages in both the years, respectively. Per cent increase in yield of IPM villages over non-IPM villages was 5.01 and 7.16 in both the years, respectively. The additional profit due to adoption of IPM strategies was Rs 15773 and 18437 per hectare over non-IPM villages in 2009 and 2010, respectively.

Key Words: IPM, non-IPM, cauliflower, diamondback moth, tobacco caterpillar, economics

Vegetable crops occupy important status in agricultural economics. They play a unique role in our daily life both in economic and social spheres for enhancing the income as well as nutritional status of masses. Cauliflower (*Brassica oleracea* L.var. *botrytis*) is an important vegetable crop of Punjab having an area of 7.9 thousand hectares with a production of about 181.68 thousand tonnes during 2009 (Anonymous, 2010). Over the years, cauliflower has been cultivated more intensively, which has resulted in high pest infestation. Diamondback moth, [*Plutella xylostella* (L.)], cabbage butterfly [*Pieris brassicae* (L.)], tobacco caterpillar [*Spodoptera litura* (Fabricius)] and aphids [*Lipaphis erysimi* (Kaltenbach)] are common insect-pests on cauliflower in Punjab. Because of lack of awareness among farmers about other alternative methods of pest control, natural forces of pest suppression/ bio-agents are not properly exploited. Cultural practices such as proper crop rotation, judicious use of fertilizers and pesticides are not being used in their perspective. However, in spite of repeated sprays, farmers are not being able to obtain good yield. This is because of lack of awareness about integrated pest management (IPM), use of unrecommended chemicals and improper spray technology. Realizing the need to have an integrated approach to tackle the insect-pests problem in cauliflower, efforts were initiated in a participatory approach. With the main aim of reducing the dependence on insecticides, IPM strategies involving biopesticides and cultural control methods were advocated. Keeping in view the above facts, the present study was planned to assess the impact of adoption of IPM strategies on the arthropod fauna and economics in cauliflower.

MATERIAL AND METHODS

A total of six villages from three district of Punjab namely Kapurthala, Fatehgarh Sahib and Amritsar were selected for implementation of IPM module in cauliflower during 2009 and 2010. One non-IPM village (farmer practice) adjoining each IPM village was also selected. A total of 25 farmers from each village were selected as target group for dissemination of IPM module. The IPM module implemented during three crop seasons in a year on cauliflower is as follows:

Early season crop (July to September)

Window 1 (July): During this month due to low pest population, no spray was recommended.

Window 2 (August): Removal and destruction of the egg masses and gregarious larvae of tobacco caterpillar and cabbage caterpillar was advocated. For control of diamondback moth (DBM), spray of Dipel (*Bacillus thuringiensis* var. *kurstaki*) @ 200 ml/acre and for tobacco caterpillar and diamondback moth attack, spray of emamectin benzoate 5 SC @ 70 g/acre was recommended. In case of less pest attack in the field, spot application of insecticide was advocated. Need based application 10 days after the first spray was advocated.

Window 3 (September): For control of diamondback moth, spinosad 2.5 SC @ 240 ml and for control of tobacco caterpillar spray of emamectin benzoate 5 SC @ 70 g/ acre was recommended. Need based spray after 10 days was

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advocated. It was also advised to pick all flowering heads before spray and to observe 7 days waiting period after each spray for next picking.

Mid season (September to December)

Window 1 (September-October): Removal and destruction of the egg masses and gregarious larvae of tobacco caterpillar and cabbage caterpillar was advised. For control of diamondback moth, spray of Halt (*B. thuringiensis* var. *kurstaki*) @ 300 g/acre and for tobacco caterpillar, spray of emamectin benzoate 5 SC @ 70 g/acre was recommended. Spot application of insecticide was advised to be carried out in case of less attack in the field, followed by need based application of second spray after 10 days.

Window 2 (November): Removal and destruction of the egg masses and clusters of larvae of tobacco caterpillar and cabbage caterpillar was recomended. No spray in this period for diamondback moth was advised. If needed, spot application of insecticide was advised.

Window 3 (December): Spot application of insecticide should be done in case of cabbage butterfly attack in the field and the spray should be repeated after 10 days, if necessary.

Late season crop (January to March)

Window 1 (January): During this month due to low pest population, no spray was recommended.

Window 2 (February): Removal and destruction of the egg masses and clusters of larvae of tobacco caterpillar and cabbage caterpillar was advised. For control of diamondback moth, spray of Dipel @ 300 ml/acre was recommended. For tobacco caterpillar and diamondback moth attack, spray of emamectin benzoate 5 SC @ 70 g per acre was recommended.

Window 3 (March): For control of diamondback moth and tobacco caterpillar, spray of emamectin benzoate 5 SC @ 70 g per acre was recommended. For control of diamondback moth, spray of spinosad 2.5 SC @ 240 ml of per acre was also recommended.

Scouts were trained regarding transfer of IPM technology in cauliflower to coordinate meetings, training camps, field days and field visits of experts. Information centers were also set up in all the six adopted villages. Charts depicting IPM technology recommended by PAU, Ludhiana for cauliflower from sowing to harvesting were displayed in the IPM centers. Need based information was also provided through pamphlets and public address system. In these villages, farmers' fields were adopted to demonstrate IPM technology in cauliflower. The baseline data regarding use of insecticide, fertilizers, cost of cultivation and yield were recorded to study the impact of IPM module. The weekly data regarding incidence of various insect pest of cauliflower and population of natural enemies were also recorded both from IPM and non-IPM farmers throughout the crop season.

RESULTS AND DISCUSSION

Incidence of insect-pests

The data on the incidence of insect-pest of cauliflower is given below:

Diamondback moth: The mean larval population of diamondback moth was low in IPM villages in comparison to non-IPM villages. It was 1.69 and 2.00 larvae/plant in IPM villages and 10.73 and 9.42 larvae per plant in non-IPM villages in 2009 and 2010, respectively (Fig. 1).

Tobacco caterpillar: The mean larval population of tobacco caterpillar was also low in IPM villages in comparison to non-IPM villages. It was 3.58 and 3.82 larvae per plant in IPM villages and 10.77 and 10.52 larvae per plant in non-IPM villages in 2009 and 2010, respectively (Fig.1).

Cabbage butterfly: The mean larval population of cabbage butterfly was low (2.42 and 2.03 larvae/plant) in IPM villages as compared to non-IPM villages (9.02 & 10.63 larvae/plant) in 2009 and 2010, respectively (Fig.1).

Aphid: The mean population of aphid was low (1.09 and 0.65 per plant) in IPM villages in comparison to non-IPM villages (5.65 and 6.22 per plant) in both the years, respectively (Fig. 1).

Natural enemies: Spiders were the main natural enemies observed. The number of spiders per plant was more in IPM villages (1.15 & 1.51) as compared to non IPM villages (0.17 & 0.16) in both the years (Fig.1).

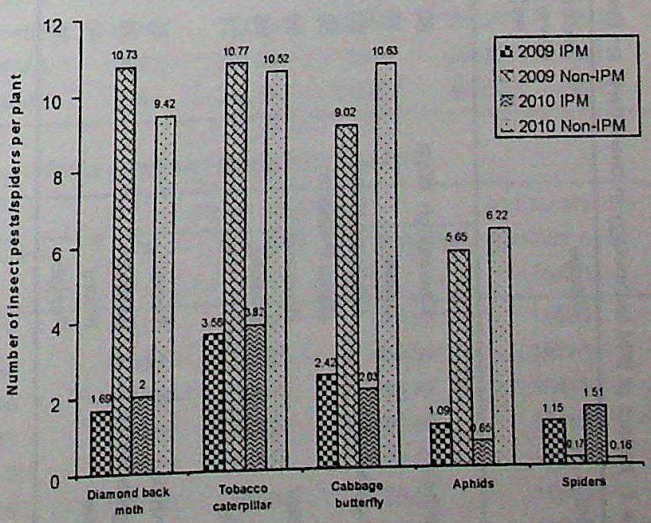


Fig 1. Population of different insect pests and natural enemies in cauliflower in IPM and non-IPM fields of Punjab.

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Table 1: Impact of IPM technology in cauliflower on the economics and net returns during 2009

District	Village	Area covered (ha)	Total number of spray/ha	Cost of sprays (Rs/ha)	Cost of Inputs (Rs/ha)	Cost of farm operation (Rs/ha)	Cost of cultivation (Rs/ha)	Yield (q/ha)	Gross Income (Rs/ha)	Net Profit (Rs/ha)
					IPM villages					
Kapurthala	Mewasingh Wala	80	4.0	4543	13165	10263	23428	438	131400	107972
	Swaal	75	4.1	4578	13150	10673	23823	440	132000	108177
Fatehgarh Sahib	Jalkhelan Kheri	55	3.2	3795	12413	10013	22425	450	135000	112575
	Bassi Pathana	60	3.3	3870	12370	10387	22757	445	133500	110743
Amritsar	Bhararíwal	80	5.3	5610	14440	10588	25028	438	131400	106372
	Dhapai	75	5.1	5538	14400	11027	25427	425	127500	102073
Punjab		71	4.17	4656	13323	10492	23815	439	131800	107985
					Non-IPM villages					
Kapurthala	Tibbe	35	7.3	8899	22124	11100	33224	419	125700	92476
Fatehgarh Sahib	Jatana	30	6.3	7463	20180	10790	30956	424	127200	96244
Amritsar	Bhoru	40	8.4	11800	24865	11719	36584	415	124500	87916
	Punjab	35	7.33	9387	22390	11203	33588	419	125800	92212

Table 2: Impact of IPM technology in cauliflower on the economics and net returns during 2010

District	Village	Area covered (ha)	Total number of spray/ha	Cost of sprays (Rs/ha)	Cost of Inputs (Rs/ha)	Cost of farm operation (Rs/ha)	Cost of cultivation (Rs/ha)	Yield (Kg/ha)	Gross Income (Rs/ha)	Net Profit (Rs/ha)
					IPM villages					
Kapurthala	Mewasingh Wala	75	3.80	4471	13285	10794	24079	444	133200	109121
	Swaal	75	3.90	4420	13273	10725	23998	452	135600	111602
FatehgarhSahib	Jalkhelan Kheri	50	3.40	4039	12542	11215	23757	445	133500	109743
	Bassi Pathana	55	3.20	4017	12485	11352	23837	452	135600	111763
Amritsar	Bhararíwal	80	4.80	5469	15128	10685	25813	442	132600	106787
	Dhapai	75	4.70	5430	15294	10852	26146	435	130500	104354
	Punjab	68	3.97	4641	13668	10937	24605	445	133500	108895
					Non-IPM villages					
Kapurthala	Tibbe	50	7.40	9130	22265	12162	35525	417	125100	91575
Fatehgarh Sahib	Jatana	50	6.50	7494	21500	12506	34006	421	126300	92294
Amritsar	Bhoru	50	8.60	10948	23262	12835	36097	412	123600	87503
	Punjab	50	7.50	9191	22342	12501	35209	417	125000	90457

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Impact on IPM strategies on the economics

The impact of dissemination of IPM strategies on the number of sprays, spray cost, cost of inputs, cost of cultivation, yield and net profit is presented in Tables 1, 2, 3 and 4.

Number of sprays: Mean number of sprays was more (7.33 & 7.50) in non-IPM villages than IPM villages (4.17 & 3.97). The per cent reduction in number of sprays was 43.11 and 47.07 in IPM villages over non-IPM villages during 2009 and 2010, respectively (Table 3).

Spray Cost: The cost of sprays in IPM villages was Rs 4656 and 4641 per hectare, however it was Rs 9387 and 9191 per hectare in non-IPM villages during 2009 and 2010, respectively. The per cent reduction in spray cost in IPM villages over non-IPM villages was 50.40 and 49.51(Table 3).

Cost of inputs: The average cost of inputs was Rs 13323 and 13668 per hectare in IPM villages during 2009 and 2010, respectively (Table 1 & 2). However, it was Rs 22390 and 22342 per hectare in non-IPM villages.

Cost of cultivation: The data presented in Table 1 and 2 showed that cost of cultivation was Rs 23815 and 24605 per hectare in IPM villages, however, it was Rs 33588 and 35209 per hectare in non-IPM villages during 2009 and 2010, respectively. Per cent reduction in cost of cultivation in IPM villages over non-IPM villages was 29.10 and 30.12 (Table 3).

Yield: From Table 4, it is evident that average yield of IPM farmers was 440 and 449 kg/ha in comparison to non-IPM villages (419 and 416 kg/ha) in 2009 and 2010, respectively. Per cent increase in yield of IPM villages over non-IPM villages was 5.01 and 7.34.

Net profit: The average net return of the IPM farmers was Rs 107985 and 108895 per hectare in comparison to Rs 92212 and 90457 of non-IPM villages during 2009 and 2010 respectively (Table 4). The per cent increase in profit in IPM villages over non-IPM villages was 17.10 and 20.38. The additional profit due to adoption of IPM module was 15773 and 18437 Rs/ha over non-IPM villages during 2009 and 2010, respectively.

From the above findings, it is evident that due to adoption of IPM technology there was reduction in incidence of insect-pests on cauliflower in both the years. The present findings corroborated the results of Burkness and Hutchison (2008) who reported 23.50 per cent reduction in insecticide applications due to adoption of IPM strategies on cabbage in IPM over non-IPM programme. They also reported 10.50 per cent increase in yield in IPM programme over non-IPM programme. The net returns of IPM

Table 3: Per cent reduction in sprays, spray cost and cost of cultivation over non-IPM in cauliflower during 2009 and 2010

District	Year	Number of sprays			Spray cost (Rs /ha)			Cost of cultivation (Rs/ha)		
		IPM	Non-IPM	% reduction	IPM	Non-IPM	% reduction	IPM	Non-IPM	% reduction
Kapurthala	2009	4.05	7.30	44.52	4561	8899	48.75	23626	33224	28.89
	2010	3.85	7.40	47.87	4446	9130	51.30	24039	35525	32.33
Fatehgarh Sahib	2009	3.25	6.30	48.41	3833	7463	48.64	22591	30956	27.02
	2010	3.3	6.50	41.54	4028	7494	46.25	23797	34006	30.02
Amritsar	2009	5.2	8.40	38.09	5574	11800	52.76	25228	36584	31.04
	2010	4.75	8.60	44.76	5450	10948	50.21	25980	36097	28.03
Punjab	2009	4.17	7.33	43.11	4656	9387	50.40	23815	33588	29.10
	2010	3.97	7.50	47.07	4641	9191	49.51	24605	35209	30.12

Table 4: Per cent increase in cauliflower yield and net profit over non-IPM in cauliflower during 2009 and 2010

District	Year	Yield (Kg/ha)			Net profit (Rs/ha)			Additional profit (Rs/ha) over non-IPM
		IPM	Non-IPM	% reduction	IPM	Non-IPM	% reduction	
Kapurthala	2009	439	419	4.77	108074	92476	16.87	15598
	2010	448	417	7.43	110361	91575	20.51	18786
Fatehgarh Sahib	2009	448	424	5.66	111659	96244	16.02	15415
	2010	449	421	6.65	110753	92294	20.00	18459
Amritsar	2009	432	415	4.10	104222	87916	18.89	16306
	2010	442	412	7.28	105570	87503	20.65	18067
Punjab	2009	440	419	5.01	107985	92212	17.10	15773
	2010	449	416	7.34	108895	90457	20.38	18437

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programme were higher due to active pest scouting, improved application timing and application on basis of action threshold. Reddy and Guerrero (2000) also reported that cost of the IPM treatments was considerably lower in IPM than that of ordinary insecticide practice (average of $62 relative to $123 per ha, respectively). Gross profit was also higher in IPM plots than in farmer's fields, ranging from $777 to $810 per ha in the IPM plots compared with $ 456 to $ 462 per ha in the insecticide-treated fields. Net profit in IPM treatments was even more and the economic savings associated with the utilization of the IPM programme amounted to $380 per ha in 1996 and $ 410 per ha in 1997. Similarly, Morallo *et al.* (2000) reported that in lowland Philippines, IPM practices resulted in lower DBM population than non- IPM farmers practices. The farmer adoption of IPM technology resulted in the 5-78 per cent increase in net income over non-IPM farmers due to lower production cost and higher yield. In IPM practices, production cost per hectare was 2 to 45 per cent lower than non- IPM practices. Insecticide application was also reduced in case of IPM farmers than non- IPM farmers. Similarly, our results showed 43.11 and 47.07 per cent reduction in number of sprays and 17.10 and 20.38 per cent increase in net income in IPM villages over non- IPM villages during 2009 and 2010, respectively. Reitz *et al.* (1999) also reported 25 per cent reduction in pesticides applications on celery crop in IPM fields over non-IPM fields. Gajanana *et al.* (2006) reported 46 per cent increase in the yield, 21 per cent reduction in cost of cultivation and 119 per cent increase in net returns in IPM fields over non-IPM due to adoption of IPM technology in tomato crop. Singh *et al.* (2002) also reported higher cost benefit ratio (1: 5.32) in IPM fields of cauliflower in comparison to non-IPM fields. Cuyno *et al.* (2001) reported economic and environmental benefits in adoption of IPM practices over non-IPM practices with reduction in use of pesticides from 25 to 65 per cent on onion.

The present findings showed that implementation and adoption of IPM technology in cauliflower resulted in the reduction of insecticide spray, cost of spray and higher economic benefits to IPM farmers.

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Laboratory Evaluation of the Relative Toxicity of Some Novel Molecules on the Resurging Tea Looper Complex on Tea

Shaonpius Mondal and A.K. Dhawan*

Department of PSES, University of Idaho, Moscow, ID, USA, 83844-2339.
**Department of Entomology, Punjab Agricultural University, Ludhiana, Punjab, 141004*
**E-mail: ashokdhawan@yahoo.com*

Abstract: India is the largest producer and consumer of tea worldwide in both quantity and quality. Dooars region of India significantly contributes to the total tea production of India. Recently, resurgence of a looper complex (*Hyposidra infixaria* Walker and *H. talaca* Walker) has seriously constrained the tea production of Dooars region. The pest population was monitored to be in the crisis phase leading to the disaster phase. To resist that disaster, immediate application of effective chemicals is of prime interest. Six new molecules including one mitochondrial uncoupler (single spectrum anthralinic diamide) and two insect growth regulators along with the conventional bio-pesticide (*Bt*) were tested in laboratory bio-assay. The insect growth regulator (IGR) novaleuron was found to be highly effective along with some other new chemicals like indoxacarb, chlorantraniliprole, spinosad and emamectin benzoate. Emamectin benzoate was found to have the highest relative toxicity. These new chemicals have enough potential to be incorporated in the integrated pest management schedule to manage the looper complex pest population build up.

Key Words: Tea looper complex, New molecule, Insect growth regulator, *Bt* formulation, insecticides.

Tea plant (*Cammelia sinensis*) is an evergreen woody perennial and India is the largest producer and consumer of tea in the world. In 2008 calendar year, India produced 980.82 M Kg of tea and an estimated production 972 M Kg in 2009 Fiscal year. Tea board of India predicted a production of more than 1000 million Kg in 2010 fiscal year. Already tea of 59.29 million USD price was exported by India in 2010. The Dooars region of North-Eastern India produce a huge quantity of tea which was 142030 thousand kg in 2008 (Tea Board of India, 2011). But if the trend of the recent production statistics of Dooars region is observed, the yield has not increased significantly over decade. The main reason behind this is an outbreak of tea looper complex.

As a long lived woody perennial, tea provides micro climate with favorable conditions and continuous supply of food for rapid built up of many phytophagous arthropod species. An estimated of 1031 arthropod species are associated with tea plantation and may cause up to 55 per cent damage to the plantation if unchecked (Hazarika *et al.*, 2009). In addition, Mukhopadhay and Roy (2009) reported more than 160 insect species in the Northern tea growing regions of India including the Dooars and Terai region, among them six species are attaining the major pest status (Gurusubramanian *et al.*, 2008). The looper, *Biston suppressaria* was previously recorded in the dooars region (Anonymous, 1994) whereas in the previous decade an outbreak of two geometrids, *Hyposidra talaca* (Walker) (Basu Majumdar and Ghosh, 2004) and *Hyposidra infixaria* (Walker) (Nair *et al.* 2008) was evaluated. Recent field observations by Das *et al.*, (2010) confirmed the dominance of *H. talaca* and *H. infixaria* over *B. suppressaria*.

Earlier, looper, *B. suppressaria* had 5-6 generation in the tea plantation, but now the looper complex generally was 7-8 broods in a year in the dooars region (personal observation). Das *et al.* (2010) extensively studied the morphological traits, diversity and seasonal occurrence of the looper complex and revealed that development periods differed intra-specifically, being 55 days for *H. talaca* and 48 days for *H. infixaria*.

In the 1960's, the insect pests of tea were mostly treated with DDT (Cranham, 1966) followed by other organochlorine compounds. In the 1990's tea plantation was mostly treated with endosulfan (TRA, 1994) followed by several pyrethroids (Murlidharan, 1992) and organo-phosphates (Gurusubramanian *et al.* 2008). Indiscriminate use of pyrethroids with sub-lethal dose accelerated the looper resurgence in Dooars region. The present situation was evaluated with a crisis phase leading to the disaster phase. This situation demands immediate evaluation of new molecules which can effectively manage pest population build up and can be incorporated in the integrated pest management schedule. In the present study, we evaluated the bio-efficacy and relative toxicity of six new molecules against the looper complex and are reporting their efficacy on the looper complex for the first time.

MATERIAL AND METHODS

All the experiments were performed in the laboratory condition and space provided by the Demdima tea garden

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of Dooars region, West Bengal, India. Larvae of *H. talaca* and *H. infixaria* were collected from untreated fields of tea and maintained in glass jar on the untreated succulent leaves of tea. Frequent observations were made to ensure their good health. Third instar larvae were later on used for the bioassay test.

Bio-efficacy and relative toxicity of six new insecticides viz., novaluron (Rimon®), indoxacarb (Avaunt®), spinosad (Tracer®), chlorantraniliprole (Coragen®), chlorfluazuron (PI 108-test chemical), emamectin benzoate (Proclaim®) and *Bt* formulation (Dipel®) were evaluated against third larval instar of *H. talaca* and *H. infixaria*. Six concentration of each insecticide were prepared by serial dilution. The larvae were given a pre-feeding starvation period of 4 hrs for ensuring highest feeding rate. Twenty five test larvae were considered for each treatment (5 larvae were kept in one petridish with 3 treated leaves). For treating the leaves with insecticides, the leaves were dipped in the respective solution of insecticidal concentration for 20 seconds to facilitate uniform spreading on them. Then the leaves were kept for 2-3 hrs in shade for drying. Untreated control was maintained along with treatments. The experiment was carried out in standard laboratory environmental conditions at a temperature of 26 ± 2 °C and 70-80 per cent relative humidity. The observations on larval mortality were recorded after 24, 48, 72 and 96 hrs of insect release. The whole experiment was replicated five times.

The data on per cent mortality was subjected to ANOVA after square root (x+0.5) transformation. The percentage mortality was calculated using the formula:

$$\text{Percentage mortality} = \frac{\text{Pre treatment count} - \text{Post treatment count}}{\text{Pre treatment count}} \times 100$$

The mortality data was converted to corrected per cent mortality by using Abbott's formula (Abbott, 1925) and mortality data were subjected to probit analysis (Finney, 1971) to calculate LC_{50} and LC_{90} values. Relative toxicity of different insecticides was calculated by taking the highest LC_{50} value of particular insecticide as standard or unity. The whole probit analysis was performed using statistical software CPCS version CPCS 1 (PAU, India) and analysis of variance was performed with SAS version SAS 9.2 (SAS Institute, Cary, NC, USA).

RESULTS AND DISCUSSION

Bio-efficacy: All the treatments were superior to the untreated control throughout the exposure period of 96 hours. Among the selected insecticides, novaluron, indoxacarb, chlorantraniliprole (renaxypyr) and emamectin benzoate showed very high toxicity whereas spinosad and *Bt* formulation showed moderately high toxicity to the test insects in comparison to control. Another IGR, chlorfluazuron proved ineffective in giving a desired level of larval mortality, hence failed to check the test insect population (Fig. 1).

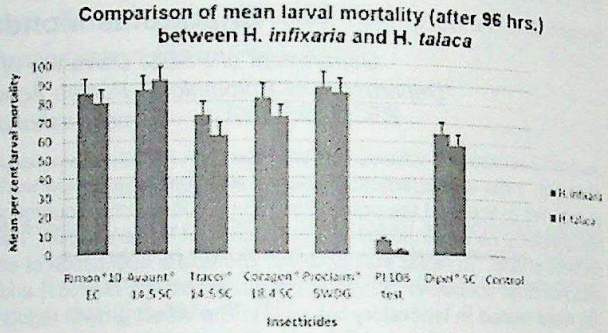


Fig. 1: Comparison of mean larval mortality between *H. infixaria* and *H. talaca* (mortality in five concentrations pooled) (*error bars = 1 SEM*).

For *H. infixaria,* at initial period of exposure, indoxacarb, emamectin benzoate and spinosad gave 100 per cent mortality in the 3rd instar larvae with higher concentration of insecticides while bio-pesticide *Bt*, IGR novaluron and mitochondrial uncoupler chlorantraniliprole (renaxypyr) took 48 hrs or more to achieve 50 per cent mortality or greater. However, initial exposure of test larvae to chlorantraniliprole treated leaves affected the feeding (larvae stopped the feeding) and within a period of 72 hrs, most of the test larvae were found dead. Novaluron, indoxacarb and emamectin benzoate produced mortality ranging from 60-90 per cent (larval count pooled after 96 hrs) (Fig. 2). Indoxacarb, novaluron, chlorantraniliprole and emamectin benzoate were at par and superior than other insecticides throughout the exposure period.

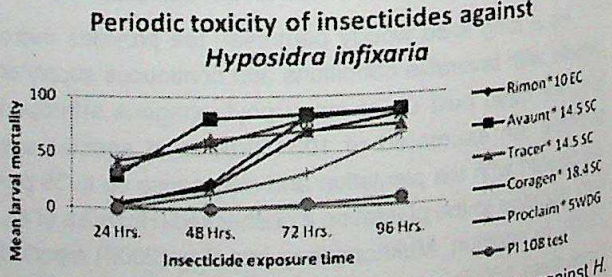


Fig. 2: Comparison of periodic toxicity of insecticides against *H. infixaria* (larval mortality in five concentrations pooled).

Almost similar trend in the bio-efficacy of insecticides was observed against *H. talaca*. With initial exposure, higher test concentrations of emamectin benzoate and spinosad resulted into 100 per cent mortality in the 3rd instar larvae and limiting the mortality to 90 per cent in case of indoxacarb. Nearly same mortality was observed in case of the other insecticides in both *H. infixaria and H. talaca.*

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However, it is clear that except chlorfluazuron, all the chemicals were highly effective in control *H. talaca* also. Although initially ineffective to produce significant mortality, the IGR (only novaluron) and mitochondrial uncoupler (renaxypyr) were both found to be highly effective after 48 hrs of exposure. In both the cases, larval feeding was affected (larvae stopped feeding) leading to high mortality with progression of time (Fig. 3).

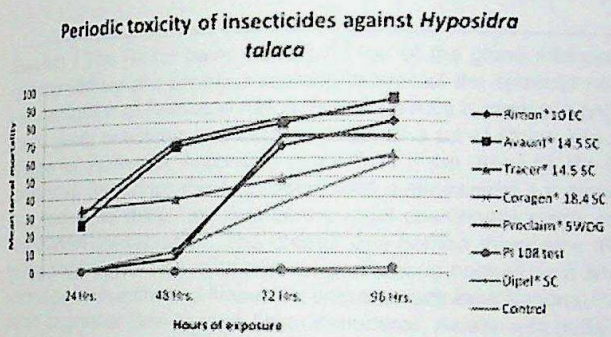


Fig. 3: Comparison of periodic toxicity of insecticides against *H. talaca* (larval mortality in five concentrations pooled).

Analysis of variance was performed to observe the difference between larval mortality in *H. infixaria* and *H. talaca* and compare the effects of treatments. Larval mortality did not differ significantly among the population of different species. This result leads to the conclusion that all the insecticides except chlorfluazuron were biologically effective for both the species with same intensity at a same time of exposure.

Relative toxicity: The LC_{50} value evaluated for novaluron, indoxacarb, spinosad, chlorantraniliprole, emamectin benzoate and *Bt* formulation for 3rd instar larvae of *H. infixaria* were 0.0019, 0.0013, 0.0037, 0.0021, 0.0018, and 0.419 respectively. The LC_{50} of chlorfluazuron was so higher (relatively ineffective molecule) that we have excluded that insecticide from the consideration. Selected insecticides gave different pattern of toxicity against the *H. infixaria* where Bt formulation showed high LC_{50} value and low toxicity to the larvae in comparison to others. Comparison of LC_{50} values of different insecticides revealed that novaluron, indoxacarb, spinosad, chlorantraniliprole and emamectin benzoate were 220.53, 322.31, 113.24, 199.52, 232.78 times more toxic than *Bt* formulation. On the basis of LC_{50} value, it can be inferred that indoxacarb is the most toxic insecticide and *Bt* formulation was the least to 3rd instar larvae of *H. infixaria*. The slope of the insecticides revealed that *Bt* formulation, chlorantraniliprole and novaluron have good knockdown (stopping of larval feeding) effect against the test insect (data not shown).

Nearly similar trend in relative toxicity was observed in the other species of looper (*H. talaca*). The LC_{50} values evaluated for novaluron, indoxacarb, spinosad, chlorantraniliprole, emamectin benzoate and *Bt* formulation for 3rd instar larvae of *H. talaca* and were 0.0021, 0.0015, 0.0041, 0.0022, 0.0016, and 0.398 respectively. The relative toxicity of the respective insecticides were 189.52, 265.33, 97.07, 180.91, 248.75 more compared to *Bt* formulation. In this case, emamectin benzoate has nearly same level of relative toxicity as that of indoxacarb. A quick knockdown (larvae stopped feeding) was observed in case of *Bt* formulation and chlorantraniliprole (data not shown).

Best to our knowledge, these new molecules (except emamectin benzoate) have been evaluated for the first time against the looper complex. However, almost all of the chemicals tested (except chlorfluazuron) were observed to possess high efficacy. Recently Das *et al.* (2010) tested different concentrations of cypermethrin and reported that *H. talaca* showed a very high LC_{50} value, which indicates the relative inefficacy of insecticides. The increased resistance and/or tolerance level of looper caterpillar. So, in this situation, with the failure of conventional synthetic pyrithroids, it is obvious to have some novel molecules which can potentially encompass the resurgence of the looper complex in Dooars. Hence, our evaluation about the relative toxicity of novaluron, indoxacarb, spinosad, chlorantraniliprole, emamectin benzoate along with *Bt* formulation is worth-making and have enough significance for the development of integrated pest management strategies against the looper complex to resist the so called disaster.

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Rhino Fate in Trouble : Study on Conservation and Management issues of Kaziranga National Park, Assam

Pranab Pal

Wildlife Institute of India, PO Box # 18, Chandrabani, Dehradun, India
E-mail : ppal@wii.gov.in

Abstract : The Rhino have existed on top of the globe intended for more than 40 million years and contain a wonderful record. The surviving Rhinos are precious representatives of the splendid heritage and history of the Rhino family unit taking place our earth. The viable utilization of Rhinos in Africa as well as Asia is immobile ongoing as this animal carries horn appeal its worth akin to gold. Seeing as last 35 years poaching has caused death of a lot of Rhino into this earth and has show the way every one the species of Rhino into struggle for existence. According to the CITES the three of the five species, the black rhino*(Diceros bicornis)*, Javan rhino (*Rhinoceros sondaicus*), Sumatran rhino (*Dicerorhinus sumatrensis*) are slowly and steadily becoming critically endangered. Presently the black rhino and white rhino are two of the most charismatic mega herbivores left on our planet and have became the flagship species of International conservation. The greater one-horned rhinoceros *(Rhinoceros unicornis)*, scheduled as endangered species by IUCN and on Appendix I of CITES, has now been cramped hooked on a small number of confined populace adding together about 3000 animal in several parks in India and Nepal. At present Kaziranga National Park (KNP) , Assam is a significant conservation values of world's largest Indian or greater One-horned Asian rhinoceros, Asiatic wild buffalo and Eastern Swamp deer population. Subsequent to concerning 100 years of protection, the Kaziranga at the present hold up a possible population of 2329 rhinos by means of 5.65% an animal increase rate . The usual density of the rhino is 3.65/sq.km with highest density of 9.25rhinos/sq.km. in the western range of KNP. The populace of one rhino into the appearance two-third of their whole populace within the entire earth. According to specialist the bulk of tigers at Kaziranga is 32.64 tigers for each 100 sq.km. The uppermost into several know tiger habitat. Kaziranga is one of the main territory of protected terrain in the sub-Himalayan girdle, and owing in the direction of the company of extremely assorted and noticeable species, has been described as a "biodiversity hotspot". The Park has been complete and intended by means of divide national park rank to make available comprehensive environment for increasing the population of wildlife or, as a corridor for secure association of animals to Karbi Anglong Hills. The park is situated in the Indomalaya ecozone, and the most important biomes of the region are Brahmaputra Valley semi- evergreen forests of the tropical and subtropical mist broad leaf forests biome and a regularly flooded alternative of the Terai-Duar savanna and grasslands of the tropical and subtropical grasslands savannas, and shrub lands biome. The Park has been shaped by means of alluvial deposit of Brahmaputra river and is a assortment of grasses interspersed by means of tropical wet evergreen and semi-evergreen forests and beels which create the area appropriate for rhino. Poaching , Erosion, encroachment, flood, siltation and Invasive species, however , are the major problems in Kaziranga's one -horned rhinoceros conservation. This paper aim of this arrangement is to evaluate the present condition of inhabitants, surroundings and conservation problems and to build up a comprehensive plan intended for the upkeep and management of rhino eternity.

Key words: Conservation and management, anti-Poaching, flood fighting, education and awareness.

There are three species of Asian rhino specifically the Indian or greater one-horned Asian rhino, the Jaban or lesser one-horned Asian rhino, and the Sumatran or Asian two -horned rhino. All the three species were plentiful and to a certain extent (*Thomas, 1997*) extensively dispersed in Asia from side to side at slightest the focus of the 19th century. In the 1980s, rhinos were regularly seen within the thin simple area of Royal Manas National Park, in Bhutan. Nowadays, they are limited in the direction of environment bounded through human-dominated landscapes, consequently so as to they frequently happen inside neighboring cultured areas, pastures, and secondary forests. The Indian rhino is, all along with the African white rhino, the second major living wage species of ground mammal and inhabits riverine lowland in India and Nepal. The Javan rhino is in the identical genus as the Indian rhino other than is a smaller species and inhabits tropical forests except mainly the length of water path. The Sumatran rhino is the smallest of all rhino species and inhabits the most dense habitat in tropical forests. Both the Indian and Javan rhinos are one-horned while *(Pho:1)* the Sumatran rhino has two horns, similar to the African rhino species.

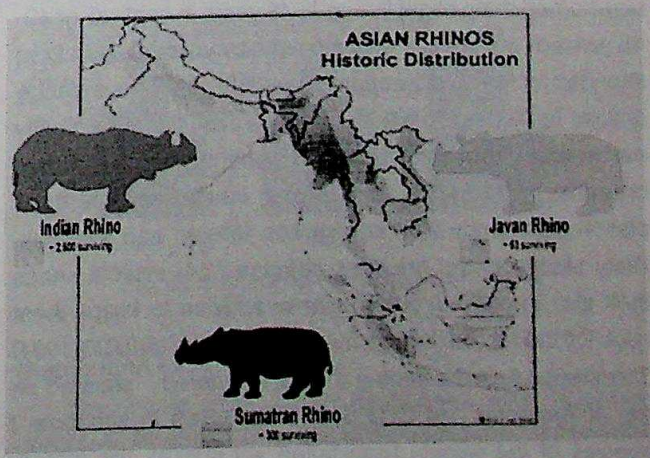


Photo 1: Rhino distribution areas in Asia

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The five livelihood species go down keen on three classes . The two Africa species , the white rhino and the black rhino diverged throughout five million years before other than the Dicerotini group in the direction of which they fit in originated within the focus Miocene, about 14.2 million years previously. The major dissimilarity flanked by black and white rhino *(Pho:2, http:// en.wikipedia)* is the form of their mouths. White rhinos contain wide flat lips intended for grazing and black rhinos encompass extended sharp lips designed for consumption plants. The Indian rhino is a grazer similar to the African white rhino. The Indian rhinoceros has broad, silver-brown skin, which becomes pinkish close to the big skin folds so as to wrap its corpse. Its upper legs and shoulders are roofed in wart-like hit. It has extremely modest corpse hair, sideways as of eyelashes, ear-fringes and tail-brush. Males build up wide neck-folds. Due to human pressure Indian rhino array has shrunk in addition to at the present they only exist in more than a few protected areas of India in Assam, west Bengal, and a small number of pairs in Uttar Pradesh and Nepal, plus a two of a kind in Lal Suhanra National Park in Pakistan.

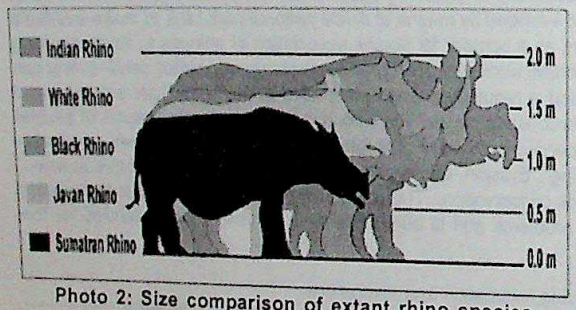


Photo 2: Size comparison of extant rhino species
(Sources : http:// en.wikipedia)

It is restricted to the tall grasslands and forests in the foothills of the Himalayas. The Sumatran rhino is a browser similar to the African black rhino. The Javan rhino is a varied feeder. A vast severe vegetarian so as to uses its days in the middle of tall grasses and marshy stumbles, the greater one-horned rhino might live up to 48 years in captivity or 40-45 years in wild, nearly everyone of it by yourself apart from intended for females by means of youthful. Male have slackly definite territories. Above all a route grazer, the rhino mostly eat grasses, however they too consume leaves, fruits, branches, and arable farm crops, inhabit riverine flood plains grasslands and contiguous forests and swamps. Daily sludge baths provides defense from insects keeps their skin in good circumstance in addition to keeps them cool. Off the record through the IUCN Red list of*(IUCN,1994)* Threatened Animals seeing that 'endangered ' planned on top of Appendix 1of CITES and sheltered in schedule I species of the wildlife fortification act (1972), the greater one-horned rhino countenances a assortment of threats due to increasing defeat of environment and poaching intended for the a immense transaction appreciated horn worn in conventional Asian medicines designed for their emblematic and supposed worth *(WWF,2002)*. The horns are subsequently shipped to Vietnam and China. They are the two *(Down to earth, April,2013)* main purpose . In China have a rhino horn is seen added seeing that a situation symbol in addition to is fewer in insist planned intended for its medicinal properties. The Vietnamese create make use of them in all and each solitary forms of medication, as well as cancer drugs and aphrodisiacs. Two-thirds of the world's Great One-horned Rhinoceroses are now confined to the KNP , Assam. They are limited to habitats surrounded by human-dominated landscapes, consequently so as to they over and over again take place in adjacent cultivated areas, pastures, and less important forests. This article is a amalgamation of Kaziranga's one-horned rhino generally look for to evaluate the at hand condition and build up the protection and management of particularly to make out issues associated by means of their inhabitants dynamics, distribution, habitats and conservation evils. This intend to rigorous shield to facilitate the extensive period endurance of rhino, in the direction of consent to appropriate environment, to act in response to upkeep evils to uphold and augment the feasible inhabitants in Kaziranga sufficiently as well as also to expand community sustain for the maintenance of rhino in perpetuity.

The Objectives of this study is to assess the crisis and prediction of management of rhino in KNP in relation on the way to its threats ,poaching ,suitable habitat, flood fighting erosion and public awareness.

MATERIAL AND METHODS

The study was conducted as a primary source of data gathered from field visits in and around Kaziranga National Park in between 2010-2013. Observations were made through personal observation, questionnaire survey among fringe villagers, Frontline forest staff and Tea garden inhabitants. Beside demographic data on Rhinoceros were gathered from forest department records. Published information were used in this study. Photographs were collected with Sony 20X optical Zoom (2.8-5.2/5.0-100.0) Potential threat zone, proximity to KNP boundary, ethnic identities and dependence level of locations were considered in sampling of the study areas.

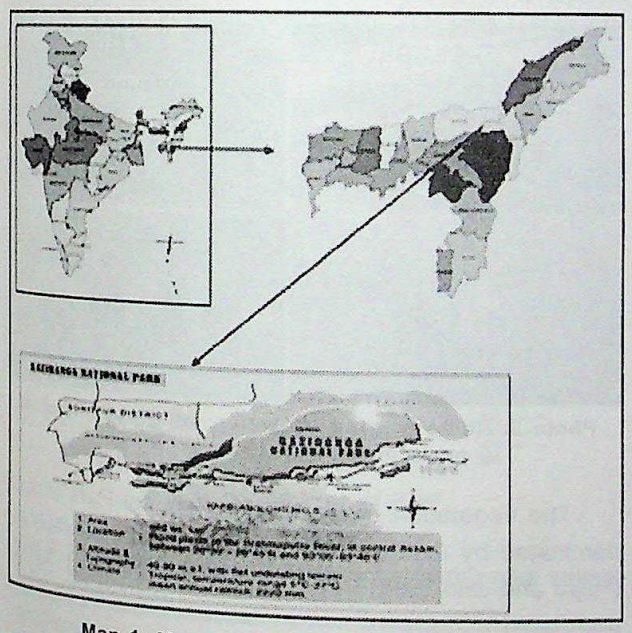
Description of Study Area

The KNP was constituted into a Reserve Forest in the year 1908 above all to save the Indian or greater one-horned Asian rhino, the figure of which reached an every one instance near to the ground to the extent of a dozen

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individuals. It became a game sanctuary in 1916 and then a wildlife sanctuary in 1950 Kaziranga was declared a national park in 1974 *(Anon,1998)* and designated as a natural world heritage site in 1985. In the year 2007 Kaziranga was declared as a Tiger Reserve. Although *Rhinoceros unicornis* is the flagship animal of the park, however KNP also holds key population of Asiatic wild buffaloes, swamp deer and provide source population for Tigers in Brahmaputra valley. Study area KNP is located in middle Assam in North East India, located on the southern bank of the river Brahmaputra at the foot of the Mikir/ Karbi Anglong Hills with Latitudes 26° 30' - 26° 45'N and Longitudes 93° 05'-93° 40,E. The arterial national highway No.37 forms the southern boundary of 430 sq.km. with an additional area *(Map:1)* of 429.4 sq.km. The riverine habitat consists above all of thick tall grassland interspersed by means of open forest, interconnecting streams and frequent small flood formed lakes/ beels which cover up about 5% of its area.



Map 1: Map of Kaziranga National Park
Source : KNP

RESULTS AND DISCUSSION

Rhino Population Growth

Serious Poaching in addition to habitat obliteration contain abridged Kaziranga rhino populace in the direction of a small number of dozen in 1908 (Gee,1964) under pressure for continued existence. Severe defense wrong way up this decline. Systematic census of rhino was primary accepted in Kaziranga in 1966. Seeing at the same time as afterward common census has been carried out within each sixth year till 2006. For the duration of 2009 and 2013 census also carried out in KNP. Rhino census in 1966 exposed that the population *(Fig:1)* had augmented to 366 by 1966 (Bonal,1999). By 1972, the population rose to 658 (ibid). Rhino population in KNP was resting on add to reaching to 939 in 1978, 946 in1984, 1120 in 1991, 1164 in1993 (Vasu,2003).

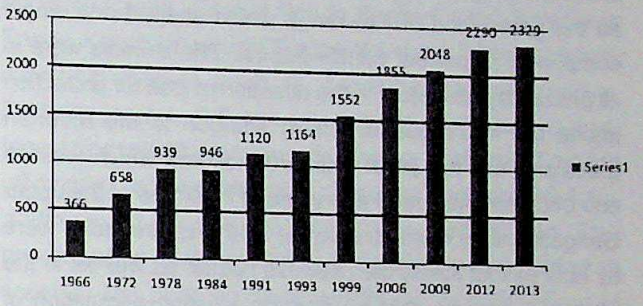


Fig. 1. Rhino Population in KNP
Source : KNP

Subsequent to concerning 100 years of defense, the park at this time hold up a feasible populace of rhinos was 1164 during 1993 by means of 929(79.81%) adults, 96(8.24%) sub-adults and 139(11.94%) calves and according to census report 1999 rhino was 1552 numbers, as a result of 1131(72.87%) adults, 164(10.56%) sub-adults and 257(16.55%) calves. The suitable augment within increase rate intended for sub adult and calf show the way in the direction of balanced age work of art of rhino population in Kaziranga during extended sprint. The Kaziranga rhino population is growing by the side of an annual augmentation rate of 5.55% in the 1999. The park houses (Fig:2) 742 males, females 909 and 411 calves (Male: Female :Calf:: 1:1.22:0.055) according to 2013. The add to in rhino given that the late 1960s reveals so as to population be able to spring back energetically at what time provided by means of enough environment and shield. During field study and data available at KNP population growth rate were carried out from2006 to 2013 and Rhino counted seeing that unidentified sex were not included at the same time since estimate was completed within the growth rate of rhino population .

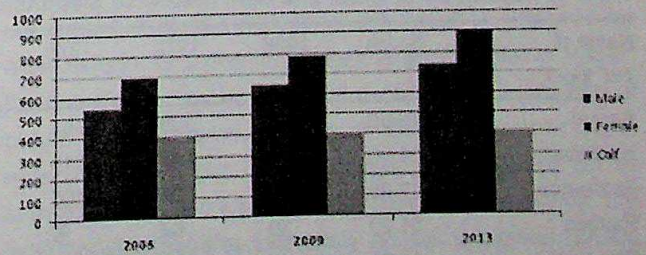


Fig. 2. Rhino Population growth in KNP
Source :- KNP

Distribution Pattern of Rhino

The whole area about Kaziranga was incredibly delicately inhabited in addition to enduringly established villagers existed merely at Bokakhat in addition to in the

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direction of its east on top of solitary side and Jakhalbandha as well as west wards on top of the additional surface. The region superseding these two places was occupied of wild animals during the adjacent forests of the Mikir hills as well as the grass land of Kaziranga which shaped one single component of perfect wildlife habitat. The animals were in all probability obligatory in the direction of look for protection inside the inaccessible hills in addition to the reverian grassland are the great Indian rhinoceros which was on one occasion dispersed every one of in excess of the upper Gangetic plains in addition to the Brahmaputra valley were by now extinct inside the previous habitat as well as in the afterward environment as well the existing population of rhinoceros inside some substantial numeral was restricted in the direction of Kaziranga only. Cruel killing of rhinoceros still in this neighborhood shaped such a circumstances so as to they became unusual along with it was supposed with the intention of merely a a small number of them -not added than a dozen, rhinos were gone through the revolve of the present centaury. The population prototype of rhino is incessantly demonstrate a progressive tendency in excess of the stage as of 1966 to 2009 . Further with the intention of 46% rhinos were dispersed in Baguri Range followed through 45.26% inside Kaziranga Range, 7.22% in eastern range and 0.90% in Burapahar range. Rhino population (Table 1) within additional adding up areas give the impression extremely a smaller amount (0.64%) in addition to it might be owing in the direction of biotic meddling. The uppermost population of rhino was recorded in Baguri wedge by means of compactness of 8.70 rhino/sq.km. while the buck population was set up Boralimara block having compactness of 2.05 individuals/sq.km. seeing that next to the normal density of 2.99/sq.km.

Rhino Habitat

The woodland type of the area has been described seeing that Eastern wet alluvial grasslands which is an early under arrest phase of a primary sere (Champion and Seth, 1968). The KNP deceit within the Brahmaputra river floodplain in addition to is almost certainly solitary of the richest , the majority charming wildlife habitat in southern Asia. This riverine environment of the park is a assortment of immense operating cost of alluvial grasslands first and foremost of tall, dense grasses interspersed by means of (Jain and Shastri,1983) tropical wet evergreen and semi-evergreen forests, interconnecting streams as well as frequent tiny lakes called Beels (Spillett, 1966) and makes the neighborhood appropriate intended for rhino. The rhinos surroundings is so as to always used (Pho : 3) the glowing laid out tracks from its self-pitying place to the feeding soil and vice versa at the same time as roaming within the grasslands as well it for eternity walks on top of such tracks which are tunneled through them in addition to laid elsewhere keen on partition compressed tracks by means of steady and usual utilize.

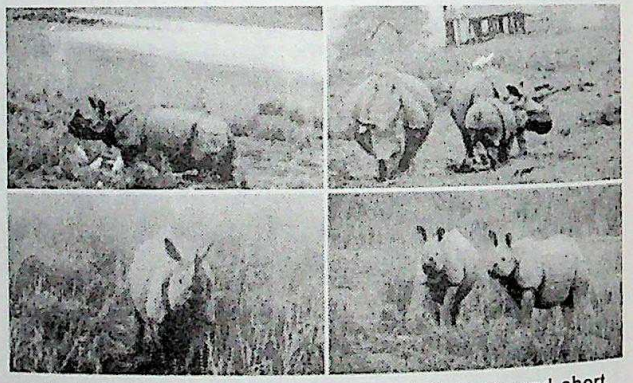


Photo 3: Rhino grazing in water, tall grass and short grass in the KNP *Source : P Pal*

The vegetation of Kaziranga National Park (map:2) dominated by extensive grasslands and classified into (Hajra and Jain,1994) three distinct categories (a) Alluvial

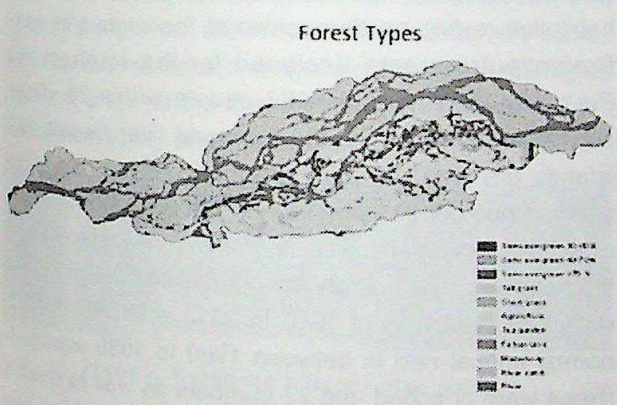
Table 1. Population of rhino and their slab wise distribution *(Source : KNP)*

Name of the block	Sq.km	1966	1972	1978	1984	1991	1993	1999	2009	Density in 2009
Baguri	79.60	157	309	388	494	507	544	684	693	8.70
Haldhibari	51.60	49	106	218	129	178	220	284	326	6.31
Kaziranga	47.90	32	34	105	81	127	108	130	209	4.36
Panbari	51.20	30	64	92	64	63	73	105	139	2.71
Bhawani	46.20	59	55	37	71	86	85	132	172	3.72
Charighoria	48.00	22	60	58	77	54	47	77	181	3.77
Tamulipathar	55.10	9	16	24	23	29	35	80	134	2.43
Boralimora	31.10	8	14	17	7	25	26	32	64	2.05
Burapahar	58.70	-	-	-	-	-	-	-	111	1.89
Addition area	215.19	-	-	-	-	60	26	28	19	
Total	684.59	366	658	939	946	1129	1164	1552	2048	2.99

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Inundated Grasslands (b) Tropical Wet Evergreen Forests (c) Tropical semi Evergreen Forests, (d) the Aquatic Flora. Study based resting on satellite imagery (IIRS, 1997) reveals so as to 98.45% of the total path area (Table: 2) is appropriate intended for rhino. One more revise yet again based lying on landsat data shows the identical neighborhood uniformly apposite designed for herbivores animal including wild buffaloo, swamp deer, elephant and hog deer which are the one -horned rhinoceros contiguous neighbors in Park (Kushwaha and Madhavan , 1986).The wet low lying locations livestock graze on grasses show being there of species like *Phragmites karka* and *Arundo donax*, the latter preferred by the rhinoceros *(Patar,1977)* . Aboutthe periphery of the water bodies and river beds as well as within marshy area, petite succulent grasses like *Cynodon dactylon*, *Hemarthria compressa*, *Andropogon* are plentiful. The short grassland has augmented from 3.72% of the park vicinity in 1973 to 10.70% in 1986 (Kushwaha and Madhavan , 1986) which is exceedingly connected by means of add to in rhino inhabitants. The park comprises supplementary that 60% *grassland (IIRS,1997).*



Map 2: Forest type of KNP
Source :KNP

Table 2. Habitation appropriateness for herbivores animal *(Source: IIRS)*

Suitability Class	Area Sq.km	Area (%)
Highly suitable	21.83	5.35
Suitable	84.75	20.78
Moderately suitable	110.65	27.13
Less suitable	80.07	19.63
Least suitable	104.26	25.56
Unsuitable	6.34	.1.55
Total	407.9	100.00

A quantity of the significant species of the tall grassland are -*Saccharum spontsneum*, the solitary nearly everyone critical rhino habitat (Dinerstein and Price, 1991 and DNPWC, 1999), *Imperata cylindrical, Narenga porphyrocoma, Cympogon pendulus, Erianthus ravanea.* Grassland prevail in the west and woodland comprises around 27% (IIRS,1997) area in the steady elevated ground. The common woodlands occupy about 27.95% of the KNP area and hold plentiful species and clusters of *Bambusa arundinaria.* Evergreen areas in the Tamulipathar Eastern Agoratoli Range, Central Range Panbari area, Burapahar Range Kanchanjuri and Baguri Western Range vicinity surround species such as *Aphanamixis polystachya, Dillenia indica, Dillenia pentagyna, Albizia procera, lagerstroemia flosreginae, Syzygium cumunii, Emblica officinalis, Taluma hodgsoni, Garcinia tinctoria, Mallotus philippensis, Bridelia retusa, Ficus rumphii* etc. The brushwood is thick by means of species akin to *Calamus* species. The park has good quality set of connections of water bodies. There are two kinds of water bodies : streams and pools. The water bodies and swampy locale, diverge dangerous for rhino, cover (Table: 3) 6.62% and 5.21% of the total park area. Main species comprise the prevalent water hyacinth *Eichhornia crassipes, Ceratophyllum demersum and Limnophila sessiflora.*

Table 3. Landuse Pattern in KNP *(Source : IIRS)*

Land use Category	1973 (%)	1986 (%)	1996 (%)	1997 (%)
Woodland	33.49	29.30	29.13	27.95
Tall grassland	47.67	41.39	51.91 -	61.01
Short grassland	3.72	10.70		3.01
Swampy areas	0.93	3.72	5.21	-
Water bodies (beels)	2.33	4.42	6.62	5.96
Sand	5.81	6.05	7.12	0.40
River water	6.03	3.45	-	1.67
Barren and other	-	0.47	-	-

Other genera include Nymphaea, Polygonum, Typha, Cyerus etc. It is relevant to eloquent that the on the whole landuse prototype of the park is not varying in addition to consequently, housing increasing number of rhinos. The flood engage in recreation an significant role within the ecology of the park. deluge by usual flooding of the alluvial unadorned makes constructive circumstance intended for rapid exterior of grows in addition to germination to uphold the grasslands. By the side of a detachment seeing that of obtain gone remains, the floods flush in another place extensive swelling of water hyacinth resting on or subsequent to a lot of water bodies. Consequently, the Brahmaputra flood is incredibly crucial designed for the continuation of rhino habitat in Kaziranga. Great parts of the grasslands are subjected in the direction of controlled burning for the duration of the winter months. Such burning is helping to take into custody additional sequence on the way to woodlands inside the elevated patches of grasslands in addition to keep hold of its present form of an perfect

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environment designed for ungulates. Six new additions to KNP all along north, west and south are notified (Table:4) by means of moreover toward make accessible comprehensive surroundings designed for growing inhabitants of wildlife or since a corridor for secure association of animals to Karbi Anglong Hills.

Table 4. KNP addition area *(Source :KNP)*

Name of the addition to KNP	Area sq.km	Function
1st addition	043.79	Habitat
2nd addition	006.47	Habitat
3rd addition	000.69	Corridor
4th addition	000.89	Corridor
5th addition	001.15	Corridor
6th addition	376.50	Habitat

The addition areas, probable on the way to hold up additional rhinos and other animals, are at the present beneath utilized through rhinoceros in addition to extra animals which can contain the consequence of elevated biotic intrusion.The fifth addition connection Park by means of planned Karbi Anglong wildlife sanctuary which more relation the Kaziranga through extra protected forest areas in Karbi Anglong hills.

Problems in Rhino Conservation

Poaching : The rhino has been subjected in the direction of incredibly dreadful incident of poaching seeing that this meticulous animal carries a horn significance it mass within gold. At the moment rhino protection category are a grave endangered species. Rhino have been on top of the edge of destruction frequent period. This is mostly as of humans. Humans give the impression to be the rhinos merely

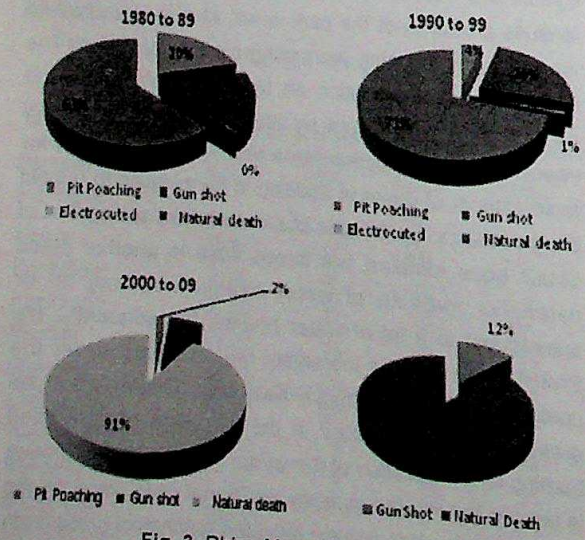


Fig. 3. Rhino Mortality in Kaziranga
Source: Down to earth & KNP

marauder. During field study data has been collected of rhino mortality from the Park boundary and more than 450 rhino has been poached by the gun shot from 1980-2013 and more than 250 rhino has been by pit poaching (Fig:3) during the year 1980-2013 from the KNP.

The rhino is poached in addition to hunted frequently designed for its horn. In Asian countries they make use of the horns designed for option medicines, ornaments and additional actually needless obsession. The poaching be able to be credited to the gullible conviction concerning the aphrodisiac and greater medicinal possessions , and the trouble is more amalgam since stipulation the declining integer of African black rhinos *(Foose and Strien, 1997)*. Wild animals such seeing that tigers, rhinos, elephants and leopards have been frequently killed by means of poachers intended for their body parts and skin, which fetch thousands of dollars on the black market. Devoid of radical exploit, a number of rhinos might be wiped out within their natural habitat in the next 15-25 years. In Kaziranga poaching consist of death caused by gunshot, pit poaching etc. The park has absorbent frontier by means of thick human habitation resting on three sides at the same time as the Brahmaputra create designed for the southern side. Presently more than 50,000 people within 75 villages survive in the region of the park and river as well as its islands are worn through poachers seeing that access gates, a number of these islands are populated by means of people, frequently cattle herdsmen, who give shelter to the poachers. The entirety rhino poached through the most recent 34 years as of 1980 to 2013 is 640 by means of normal annual rate in between 1980 to 1989 average 30 rhinos were poached and 23 numbers as well as poached from 1990 to 1999 where as average 6 rhinos has been poached during the year 2000 to 2009, according data available 8 rhinos were poached each year from 2010 to 2013 within and outer surface in the Park Assam . A substantial numeral of human being concerned inside, the rhino poachers were arrested and a number of as well killed. Poaching while continues and considered seeing that the main danger in the direction of park.

Flood : Flood is on the whole in charge intended for creating diverse location circumstances in addition to top soil configuration harbouring diverse vegetation category.The whole Park has been shaped through alluvial depositions from Brahmaputra river in addition to its tributaries which hold immense quantity of silt all through rainy season every year. The deepness of flood water might (Pho :4) more than a few meters *(Baruah,1998)* as of 1 meter to 5 meters. According on the way to Indian Institute of Remote sensing (IIRS),elsewhere of the total area of the

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park 5.96% area is roofed by means of perennial aquatic bodies. A lot of river islands in the vicinity recognized seeing that'chapories' of a variety of dimension have been shaped through smooth depositions the length of the northern boundary of the park. The altering courses of stream contain as well caused solemn incursions keen on rhino habitat. All through floods nearly all of the animals as well as the rhinos encompass in the direction of migrate as of the park along with obtain protection on the contiguous far above the grounds in Karbi Anglong hills with anywhere they may well come across shelter. These areas are occupied and the defense of rhinos throughout the period of relocation becomes an ascending chore. A few animals migrating to the Mikir Hills all the way through the inhabited villages as well as crossways the artery acquire killed by means of poachers and speedy poignant motor vehicles. In addition ,the rhino contain toward endure as of deficiency of silage along with too beginning underfeeding at what time floodwater continues in the direction of immerse meant for longer period. During the most recent four decades the incidence of floods, on top of normal has been two in a decade, solitary which within each decade was very serve . Due to various reasons, mainly deforestation in the higher catchment areas of the Brahmaputra, the strength of the flood is incessantly on the increase.

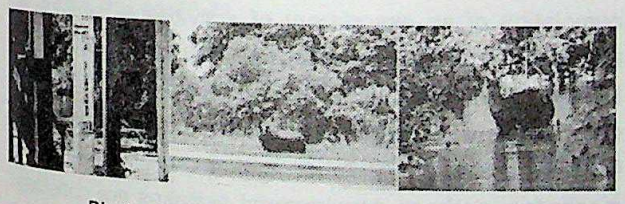


Photo 4. Kaziranga affected from flood
(Source : KNP)

Erosion :- Erosion is solitary of the most important issue in concert a imperative function resting on the potential of the park. Every year great acquaintance of terrain from the Northern boundary (Pho:5) are washed away through the Brahmaputra river. These accumulation steadily acquire reputable within the form of little islands in addition to are occupied by means of grassland consequently forming idyllic environment intended for rhino. A number of time the areas windswept previous are restored by means of serious silt depositions. The area of the park, attractive keen on description the erosion as well as erosion, is 408 sqkm IIRS,(1997). Therefore the erosion is a serious problem which causes shrinkage of the park geographical area in addition to thus reduces the environment meant for the wild animals.

Crisis of Invasive Plant Species: Invasion of exotic species is the mostly vital worldwide scale problem

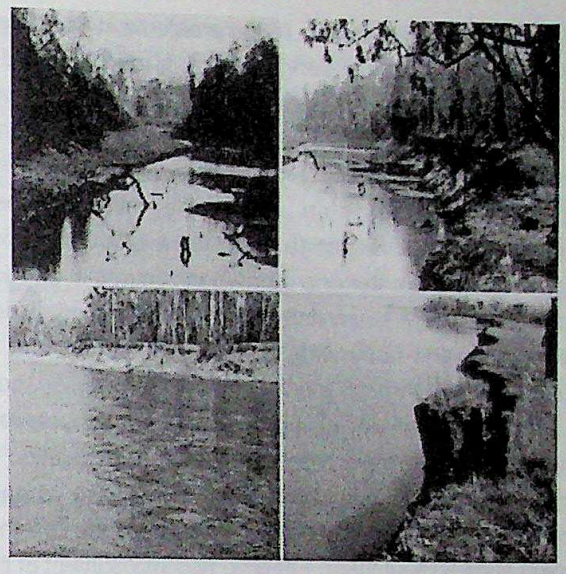


Photo 5. Bank Erosion Northern boundary in KNP
(Source : P Pal)

experienced through the usual ecosystem. It is well thought-out (Heywood,1989) seeing that one of the main threats in the direction of biological diversity. KNP as well similar to every one additional PAs countenance biological invasion the plant communities regarded are Mimosa *(Mimosa invisa)*, wild rose *(Rosa indica)* and water hyacinth *(Eichhornia crassipes)* as well a native of Brazil. In the route of occasion , this has multiply to KNP from side to side seeds accepted through run off in addition to started invading the alluvial plains of KNP. Owing in the direction of its productive flowering and making of seeds yearly, the probability of its invasion on the way to the grassland has turn out to be alarming. In Kaziranga , particularly on the way to rhino facing problem alongside invasive unfamiliar plants species. Invasive plants have the possible to hold back the increase of edible silage grasses which, in revolve, injure the habitat of rhino and supplementary wild animals. Providentially in this Brahmaputra alluvial plain of KNP and dissimilar the problem countenance by numerous PAs nearly everyone widespread weeds of invasive species like *Lantana camara, Eupatorium odoratum, Ageratum conyzoides, Mikania macrantha, Parthenium hysterophorus,* etc. are not merely that problem in detail the majority of these are not present. Seeing as the wetlands and grasslands of the park are an essential fraction designed for continuous continued existence of a lot of imperative fauna such as rhino, buffalo, swamp deer etc. the management authority is facing problem for containing siltation and weed invasion.

Rhino Conservation : A way forward

Based on top of surveillances as well as analysis of accessible in sequence on the present standing of rhino,

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their environment in addition to the problems in Kaziranga, a widespread protection along with organization scaffold is urbanized to address a multifaceted place of problems that go further than the biological and ecological concerns of rhino to accomplish the avowed objectives of extensive expression conservation and management. These strategies and actions aim to protected a brighter outlook intended for the greater one -horned rhinoceros in addition to designed for the ecosystems they dwell in by protecting environment and controlling poaching. Enhancement of habitat attached through means of sustained caution, hold up as of local people, ability building of the employee, suitable research, monitoring in addition to evaluation to consolidate the conservation accomplishment of one-horned rhinoceros lies at the compassion of this conservation arrangement. Effective accomplishment of the conservation measures based on sound ecological arguments outlined here will assist in ensuring the long term practicality of the rhino in KNP. Following strategy will mainly involves strengthening of the present system.

1. **Anti-poaching plan :** (a) Concentrated perambulation (b) Construction as well as repairing of roads in addition to bridges (c) Stipulation of top secret Fund (d) Strengthening wireless system (e) Provide of sophisticated arms (f) Permission of patrolling pathway (g) Management in the midst of various law enforcement group (h) Elephants on top of shield along with their health care (i) Organization in sequence set-up.
2. **Habitat Improvement :** (i) weed abolition (ii) De-siltation (iii) Grassland on fire (iv)Passage.
3. **Flood fighting measures :** (a) Boat Line permission (b) Establishment of impermanent camps (c) Highland creation (d) Upholding of boats.
4. **Research and Monitoring :** (i) Research (ii) Animal Census (iii) Monitoring procedure .
5. **Amenities to staff : (a)** Providing adequate facilities (b) Training to personnel (c) Reward and incentives (d) Conservation education and awareness generation (e) Eco-development programme (f) Translocation

Conservation Values

Kaziranga National Park is one of the largest lawfully protected areas beneath the Burma Monsoon Bio geographical area that hold up fauna ranging as of the soil invertebrates in the direction of mega fauna such seeing that the Rhino as well as the elephant. By means of adequate protection in addition to *in-situ* conservation endeavor that date overturn in the direction of a century, the grasslands in adding up to the mega fauna encompass been able to co-evolve within such a way that one of the main assemblages of these can be seen today within the wild. Prominent in the midst of them are the compelling 'BIG FIVE' the great Indian one horned Rhinoceros (*Rhinoceros unicornis*), The Asiatic Wild Buffalo (*Bubalus bubalis*), The Asiatic Elephant (*Elephas maximus*),The Swamp deer (*Cervus duvauvceli eanjitsinghi*), The Royal Bengal Tiger (*Panthera tigris*).The Park has outstanding worldwide protection worth and has been emblazoned as World Natural Heritage Site in 1985 beneath criteria N (ii) and N (iv) of UN management intended for shield of World's Cultural and Natural Heritage. An idyllic environment for in-situ conservation of numerous threatened species, the Park protected the major inhabitants of Greater Indian Rhinoceros (*Rhinoceros unicornis*) as well as many other threatened species. Rhinos are increasing other than inhabitants are motionless inside danger. Assam's One -horned rhinoceros protected area contain enabled this inaccessible condition in India in the direction of be one of the most excellent rhino achievement stories. With more then two-third 75% of the world's surviving population of the *greater one-horned rhinoceros (Rhinoceros unicornis)* concentrated in one place, Kaziranga has a extraordinary as well as exceptional function to take part in intended for conservation of the species. The protection of rhino in addition to other wild animals be able to achieved from side to side triumphant completion of an assortment of activities included in the arrangement along with usual run of fund is a pre-requisite to achieve the goals. Environment development as well as defense, intensification anti-poaching behavior, flood fighting actions, conservation education line up, study and monitoring, and eco-development activities are considered necessary to hold up the increasing rhino population . It is essential to effort on top of the ground along with in the strategy arena to make out not just the evils opposite these species, other than the fundamental causes as glowing. The conservation efforts ought to give the impression of being away from the border of the Park to go a extended approach in securing a intense prospect intended for the rhino. Strong conservation pledge is necessary for the extended expression protection and management of the rhino in KNP.

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Phyto-and-Zooplankton Composition and its Relation to Water Quality Status of Parashari River in Vidisha, Madhya Pradesh

Jyoti Raghuwanshi, Subhash C. Pandey and Subrata Pani[1]

Department of Chemistry, G.G.G.P.G. College, PGBT campus, Bhopal
[1]Environmental Research laboratory, Environmental Planning and Co-ordination Organization, Bhopal
E-mail: jyotiraghuwanshi93@yahoo.com

Abstract: The present study was conducted on planktonic composition of Parashari River in relation to nutrient accumulation from adjoining sewage and storm water inlets. Water samples were collected from 5 stations of the river in different seasons for analysis of various physico-chemical and biological parameters. Results obtained on various physicochemical and biological parameters showed that Station-1 and 2 were more polluted compared to remaining stations. The River has rich assemblage of phytoplankton with some pollution indicator species like *Anabaena, Fragilaria, Pediastrum, Spirogyra, Zygnema, Volvox Cosmarium*, etc. The presence of these phytoplankton species in considerable quantities seems to be under acute pollution threat. The study concluded that due to discharge of untreated sewage into the river, the water quality of river has been deteriorated and the potable nature of water is being lost. Reducing domestic waste water discharged into the river is the way to improve water quality of the Parashari river. High values of BOD and COD on Station 1 and 2 indicate eutrophic conditions in the river which is also an indication of organic pollution at these locations of the river pollution. The main reason for these values that Station 1 and 2 are located in the middle of the town whereas Station 3, 4 and 5 are located outside of the town.

Keywords: Zooplankton, phytoplankton, water quality and pollution indicator.

Plankton is one of the important components of any ecosystem and are of immense value as food and play an important role in the disposal of sewage and in the natural purification of polluted waters and are very sensitive to the environment they live in, any alteration in the environment leads to the change in the plankton communities in terms of tolerance, abundance, diversity and dominance in the habitat. Therefore, plankton population observations are often used as a reliable tool for biomonitoring studies to assess the pollution status of aquatic bodies (Mathivanan and Jayakumar, 1995). In a water body there usually occurs a seasonal qualitative fluctuation in planktonic population in tropical and temperate climates (Tiwari and Chauhan, 2006). Both phytoplankton and zooplankton supports the economically important fish populations. The phytoplankton population usually includes *Bacillariophyceae, Chlorophyceae* and *Cyanophyceae* while zooplankton comprises of *Rotifers, Cladocerans* and *Copepods*. The zooplankton community is influenced by the physico chemical parameters of the water which also bring about seasonal changes in their life process and population dynamics. The pesent study was conducted to evaluate information about similarities and dissimilarities between sampling stations, to recognize water quality variables for seasonal variations in river water quality and the affect of pollution sources on the water quality parameters using phytoplankton and zooplankton characteristics to assess the water quality of the River.

MATERIAL AND METHODS

Description of the study area

Ganj Basoda is a well known town and a municipality in Vidisha District in the State of Madhya Pradesh, India. It is located at 23.85^0 N – 77.93^0 E. River Parashri in Ganj Basoda is a victim of water pollution which flows through its heart. It is formed by the confluence of two sewage drains and forms a small watershed. A stop dam was constructed on the Parashari River to divert part of the water for irrigation purposes. The river starts from Parshora village, near to Ganj Basoda. It flows through Derkhi Lake and Bhagharru village and finally joins in Betwa River, a major river in Madhya Pradesh.

Sampling Stations: In order to determine the water quality of the river, five stations were chosen for sample collection in the study area along the stretch of the river which described below-

1. Ganj basoda- Tyonda raod, patrol pump
2. Ganj basoda- Parashari stop dam
3. Kanjana village
4. Jugai village
5. Srawda village.

Station- 1 and 2 are situated in the middle of the town, station- 1 receives a large amount of raw sewage from its densely populated habitation. Station- 2 is surrounded by vegetable market, marriage halls, inhabited and hospital. It

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receives residential wastes, untreated sewage, urban pollutants, animal waste and solid waste.

Stations -3, 4 and 5 are situated at downstream and at a distance of 5 and 15 km, respectively, after the town of Ganj Basoda. It receives agricultural runoff from its catchment. The people of this area work mainly in agriculture in nearest places.

For the study of zooplankton and phytoplankton, water samples were collected seasonally for a period of 2010-2012. One liter of water was filtered through plankton net of bolting silk No.25. Filtered water sample was preserved in 4% formalin and few drops of glycerin were added to it and was kept aside overnight for better sedimentation. Supernatant plankton free water was removed and settled concentrated sample were enumerated by Sedgwick-Rafter Cell method. For their numerical estimation, the organisms were observed under light microscope using "Sedgwick Rafter Cell" as per procedure given in standard methods (APHA, 1991). Average of 5 to 10 counts for each sample was taken into account and results were expressed in number of organisms / liter.

RESULTS AND DISCUSSION

Physico-chemical Quality

The present study reveals that the seasonal changes are the major factors in fluctuation of most of the physicochemical characters of the water. Most of the parameters were higher in summer which may be due to high temperature, evaporation and low water level and minimum in winter due to increased water level and low metabolic activities (Fig. 1). At Station 1 and 2 may be contribution of high pollution load by discharges of wastewater from urban agglomerations located upstream to these locations or due to human / animal activities in the river e.g. washing, defecation etc. Observed values clearly indicate that river water is moderately polluted by organic wastes. In the case of station 3, 4 and 5 land use covers partly agricultural lands and lake of residential area so values are low.

Seasonal variation of physico-chemical properties of different study sites of Parashari River is shown in Table-1.

The pH of the samples analyzed was slightly alkaline in nature with an average value of 7.6-8.2, 7.9-8.2 and 7.2-7.4 for the winter, summer and rainy season, respectively. It has been seen that pH values are higher in summer and winter than rainy season. The EC values of the samples analyzed was slightly alkaline in nature with an average value of 0.6-0.8mS/cm, 0.8 -1.4mS/cm and 0.7-1.0 for the

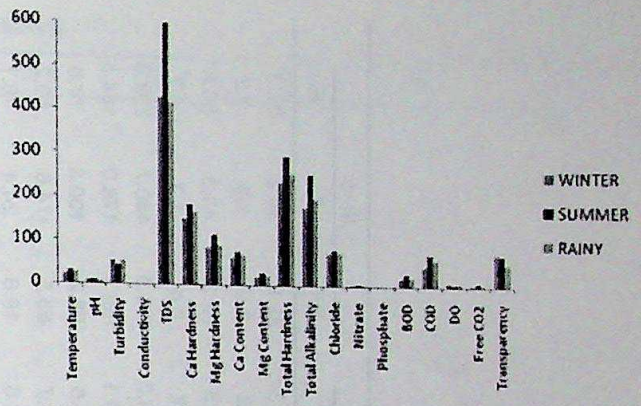


Fig. 1. The seasonal representation of Physico-chemical parameters.

winter, summer and rainy season, respectively. The mean of EC values did not vary so much between summer and rainy winter season however was found to be significantly lowered in winter. The concentration of chloride of the Parashari river ranged from 61.7-118.0mg/l during summer, 51.9-94.5mg/l during rainy, 49.4-97.0mg/l during winter. The minimum value of nitrate is 1.0mg/l and maximum value is 2.8mg/l for the samples analyzed. The values of nitrate and phosphate varies from 1.0-2.8 and 0.4-1.6 respectively. The value of BOD in the present study was highest on Station-1 and 2 as compared to Station-3, 4 and 5. The value of BOD was more in summer and indicates that river can be slightly polluted at station 1and 2. The higher values were recorded due to organic waste discharge from various sources Station -1 and 2 COD exceeded within the range of 36.0-86.0mg/l due to persistence of septic or eutropic condition or the combination of both the COD level. At station- 4 COD got reduced may be due to effect of dilution of polluted water with natural water.

Phytoplankton

During the study period 34 species of phytoplankton were recorded from the river. Among these *Bacillariophyceae* comprised of 15 species followed by 13 species of *Chlorophyceae* species and 6 species of *Cyanophyceae*. Among these, *Bacillariophyceae* was the most dominant class (41%) followed by *Chlorophyceae* (39%) and *Cyanophyceae* (20%). In the present investigation, the phytoplankton fluctuates seasonally and its density was high during summer and low during winter. Similar observations were also reported by Sadguru *et al.* (2002).

Phytoplankton count also registered higher values during winter seasons. This findings gains support from the similar observations of Kamat (2000) and Singh *et al.* (2002). Evidently in polluted zones, percentage of *Cyanophyceae* was higher when compared to

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Table 1. Seasonal variation of physico-chemical properties of different study stations

Parameters	St.-1			St.-2			St.-3			St.-4			St.-5		
	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R
Temperature	21.6	29.4	26.4	21.6	27.8	26.7	21.8	29.6	26.2	21.7	30.0	26.3	22.5	30.2	27.3
pH	8.2	8.0	7.4	8.1	8.2	7.4	7.8	7.9	7.2	8.0	8.0	7.2	7.6	7.9	7.2
Turbidity	58.5	50.5	54.8	55.0	40.8	50.0	55.3	42.5	47.5	43.5	35.0	51.5	52.3	48.3	56.8
Conductivity	0.8	1.4	0.8	0.7	0.8	1.0	0.7	1.2	0.9	0.7	1.0	0.7	0.6	1.3	0.7
TDS	604.7	824.1	408.2	450.1	541.9	539.8	407.0	599.8	446.1	356.6	581.7	378.2	315.9	480.7	298.8
Ca Hardness	172.8	196.0	179.1	159.3	199.5	184.3	124.8	165.3	153.3	149.0	178.8	154.1	156.1	178.0	164.8
Mg Hardness	95.3	126.0	111.3	89.3	124.5	107.0	74.8	115.3	78.3	91.5	106.3	76.6	68.2	100.3	77.0
Ca Content	72.6	82.3	75.2	66.9	83.8	77.4	52.4	69.4	64.4	62.6	75.1	64.7	65.5	74.8	69.2
Mg Content	23.1	30.6	27.0	21.7	30.3	26.0	18.2	28.0	19.0	22.2	25.8	18.6	16.6	24.4	18.7
Total Hardness	268.0	322.0	290.4	248.5	324.0	291.3	199.5	280.5	231.5	240.4	285.0	230.8	224.3	278.3	241.8
Total Alkalinity	186.3	276.5	223.5	201.0	247.0	209.8	184.5	264.3	201.0	166.3	243.0	179.3	157.0	241.5	176.5
Chloride	86.6	118.0	94.5	97.0	94.0	85.5	49.4	64.2	64.3	57.1	61.7	51.9	81.2	79.0	75.5
Nitrate	2.1	2.8	2.2	2.2	2.8	2.4	1.3	2.2	1.9	1.0	2.1	1.4	1.6	2.1	1.9
Phosphate	1.0	1.1	1.5	1.5	1.4	1.6	0.6	0.8	0.6	0.8	0.4	0.7	0.5	0.6	0.6
BOD	23.5	38.0	27.5	21.0	36.5	25.0	14.5	24.0	12.5	12.0	24.5	22.3	17.0	21.0	13.0
COD	52.5	77.0	64.5	57.5	86.0	55.5	40.5	68.0	71.5	38.0	57.0	52.5	36.0	71.0	51.5
DO	8.8	3.5	6.6	8.2	3.4	6.2	8.1	5.2	6.3	10.4	6.6	6.9	9.8	7.3	6.8
Free CO2	4.1	11.7	4.9	4.3	10.6	4.0	1.7	2.6	0.3	0.0	6.5	1.5	0.0	4.9	2.0
Transparency	54.5	51.6	46.0	55.9	52.2	44.5	82.8	79.0	54.8	74.4	84.8	52.8	98.3	96.1	59.8

W- Winter, S- Summer and R- Rainy

All the parameters are in mgl-1 except temperature (°C), electrical conductivity (mScm-1) and turbidity (JTU)

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Table 2. [illegible]

Class	[illegible]
Bacillariophyceae	
Chlorophyceae	
Cynophyceae	

+= rare, ++ [illegible]

Chlorophyll observation al., 2006).

Zooplankton

The zo Rotifera, C study perio the river. A followed by Protozoa 3 the most

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Table 2. Distribution of phytoplankton groups in different stations

Class	Phytoplanktonic species	St- 1	St- 2	St- 3	St- 4	St- 5
Bacillariophyceae	*Amphora sp.*	-	-	+	+	+
	Cyclotella	+	+	+	+	+
	Cymbella sp	+	+	+	+	+
	Diatoma	++	++	+	-	-
	Epithemia sp.	+	+	-	-	-
	Fragilaria sp.	+	+	+	+	+
	Frustulia sp.	+	+	+	+	+
	Gomphponema sp.	+	+	+	+	+
	Melosira granulata	+	+	+	+	+
	Navicula grimmi	+	+	+	+	+
	Nitzchia sp.	+	+	+	+	+
	Pinnularia sp.	-	-	-	+	+
	Surirella	-	-	-	+	+
	Synedra sp.	+	+	+	+	+
	Tabellaria sp.	+	+	+	+	+
Chlorophyceae	*Ankistrodesmus falcatus*	+	+	+	+	+
	Arthrodesmus convergens	+	+	+	+	+
	Cosmarium depressum	++	+	+	+	+
	Closterium acutum	+	+	+	+	+
	Pandorina morum	+	+	+	+	+
	Pediastrum sp.	+	+	+	+	+
	Scenedesmus quadricauda	+	+	+	+	+
	Selenasturm westii	+	+	+	+	+
	Spirogyra sp	++	++	+	+	+
	Staurastrum sp.	+	+	+	+	+
	Tetraedron sp.	+	+	++	+	+
	Volvox sp	++	++	+	-	-
	Zygnema sp.	+	+	+	+	+
Cynophyceae	*Anabaena sp.*	+++	+++	++	+	-
	Microcystis aeruginosa	+++	+++	+	-	-
	Merismopedia glauca	++	++	+	-	+
	Rivalaria sp	+	+	+	+	+
	Spiruiina princeps	+	+	+	+	+
	Spirulina iabyrinthiformis	+	+	+	+	+
	Gioeotrichia sp.	+	+	+	+	+

+ = rare, ++ = common, +++ = dominant, - = absent

Chlorophyceae and *Bacillariophyceae*. The present observations are in conformity with earlier finding (Kiran *et al.*, 2006).

Zooplankton

The zooplankton population of the river usually includes *Rotifera*, *Cladocera*, *Copepoda* and *Protozoa*. During the study period 20 species of zooplankton were recorded from the river. Among these *Cladocera* comprised of 7 species followed by *Rotifera* 6 species, *Copepoda* 4 species and *Protozoa* 3 species. Among these *Cladocera*(34%) was the most dominant class followed by *Rotifera*(30%), *Protozoa*(20%) and *Copepoda*(16%). The zooplankton population also fluctuated seasonally. Similar findings were also reported by Biswas and Konar (2001), the density was high during summer and low during winter in this study area. Evidently in polluted zones, percentage of *Rotifera* and *Protozoa* was higher when compared to *Cladocera* and *Copepoda*.

Form the present study, DO values 3.4-10.4 mg/l observed during experimental time indicated the suitable environmental condition for the growth of organisms. pH also affects photosynthesis, respiration and fish production (Philip, 1993). Many works have revealed that *Cladocera*,

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Table 3. Distribution of Zooplankton groups in different Stations

Class	Zooplanktonic species	Station-1	Station-2	Station-3	Station-4	Station-5
Rotifera	*Brachionus falcatus*	++	+++	+	-	+
	Brachionus caudatus	+	++	+	+	-
	Keratella tropica	+++	+	++	-	+
	Lecane sp.	++	+++	+	+	+
	Monostyla	++	+	+	+	+
	Trichocera	+	++	+	++	+
Cladeocera	*Alonella*	+	+	+	+	+
	Bosmina sp.	+	+	+	++	++
	Ceriodaphnia	+	++	+	+	+
	Chydorus sphaericus	+	+	+	++	++
	Daphnia similis	+	+	+	+	+++
	Daphnia sp.	+	+	+	+++	+
	Daphnia lumholtzi	+	+	+	+	+
Copepoda	*Cyclops sp.*	+	+	+	++	+
	Diaptomus	+	+	+	+	++
	Limnocalanus	+	+	+	+	++
	Nauplius	+	+	+	+	+
Protozoa	*Vorticella*	+++	++	+	-	-
	Ostracods	+++	++	++	-	+
	Cypridopsis	+	+	++	+	-

+ = rare, ++ = common, +++ = dominant, - = absent

epilethic and *epiphytic* algae, *Gomphonema, Anabaena, Fragilaria, Pediastrum, Spirogyra, Zygnema, Volvox Cosmarium*, etc occurred and abundant most in water with high organic nutrient. In the work of Saliu and Eruteyal (2006) who investigated the gutter in Lagos metropolis found that *Cladocera* was the most abundant zooplankton in the gutter with high organic constituent. The *protozoan* maximal apparently coincided with full flood and early dry season as observed by Sowunmi (2001) for different inland water. In the present study, similar results were also recorded at station- 1 and 2.

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Indian Journal of Ecology

Icthyofaunal Composition in Idukki Reservoir, Kerala, India

Simimole Sebastian and Joice V. Thomas[1]*

Department of Zoology, St.Berchmans College Changanasseri, Kottayam-686 101 Kerala, India
[1]NETFISH- MPEDA, Vallarpadam P.O, Ernakulam-682 504, Kerala,India
**E-mail: joicevthomas@gmail.com*

Abstract: Idukki reservoir, the largest reservoir in Kerala was investigated for a period of three years (2007-2010) to study the ichthyofauna of the reservoir. In the present study, a total of 19 species of fish belonging to 18 genera, 11 families and 6 orders were recorded in the reservoir. Family Cyprinidae was dominated by contributing 43.36% of the total fish. The study also revealed that Idukki reservoir possessed a moderate fish composition and diversity when compared to other large reservoirs in the country. Species *Ompok bimaculatus* recorded the highest catch in terms of abundance and *Channa gachua* recorded the highest biomass. Measures for the increase in fish production in the reservoir are also discussed.

Key Words: Reservoir, fish composition, abundance, biomass

India is one of the mega biodiversity countries in the world and occupies the ninth position in terms of freshwater mega biodiversity (Mittermeier and Mittermeier, 1997). In India there are 2500 species of fish of which 930 live in freshwater and 1570 are marine (Kar, 2003). Indian reservoirs preserve a relatively rich variety of fish species. The present reservoir area of India is about 50% of total reservoir area in Southeast Asia. However, despite having such a vast resource, the majority of these reservoirs are not being scientifically managed for fisheries. Due to this reason, the per hectare fish production of Indian reservoirs is very poor (Desai and Srivastava, 2004). The fish yield from Indian reservoirs is rather very poor varying from 0.05 kg/ha in Bihar to 35.5 kg/ha in Himachal Pradesh with national average of 20 kg/ha (Sugunan, 2011).

Although, among the maritime states of India, Kerala occupies foremost position in marine fish production, accounting for over 20% of the total landings in the country, its contribution to inland fish production is only negligible (2.20%) and this is primarily due to the inadequate attention received by this sector (Padmakumar *et al.*, 2008). According to Inland Fish Statistics in the year 2005-2006, the marine fish production from Kerala was 5.59 lakh tonnes whereas the inland fish production was only 0.78 lakh tones (Padmakumar *et al.*, 2008). Owing to manageable size, all the reservoirs in Kerala are logistically suitable for fish production. Despite the existence of many such small and medium reservoirs in the state, efforts to develop them on scientific lines for fish production are wanting. A perusal of literature indicates that no major initiative has been taken to create a database on the ecosystem functions and production potential of reservoir in the state. Very little information is available on their water quality and biotic communities (Padmakumar *et al.*, 2008). Considerable studies on fish diversity from reservoirs and lakes in India have been carried out during the last few decades (Sreenivasan, 1984; Valsangakar, 1987; Devi, 1997; Kar and Dey 2000; Srinivas, 2007; Negi, 2008; Rao *et al.*, 2011). However, not much study has been conducted so far in Idukki reservoir in Kerala, though it is the largest reservoir in the state except a preliminary study conducted by Gopinath and Jayachandran (1984) and Nair (1988). Therefore, this study is aimed to document the fish resources and its diversity in the Idukki reservoir in Kerala, India.

MATERIAL AND METHODS

The Idukki reservoir is roughly 'V' shaped, situated at an altitude of 693 m above sea level. When full, it has a water spread area of 23.1 sq. miles (59.83 sq.km) with depth varying from 50 to 80 m and this storage regulates the yield of over 250.7 sq.miles (1649.3 sq.km) of Periyar and Cheruthoni catchments. The Idukki hydro-electric project encompasses 3 dams. They are Idukki arch dam (09° 50" 30'N latitude and 76° 58" 40'E longitude) across Periyar, the largest river in Kerala, at Idukki gorge; Cheruthoni a straight concrete gravity dam (09° 50" 48'N latitude and 76° 58" 00'E longitude) across the tributary River Cheruthoni and Kulamavu dam (09° 47"15'N latitude and 76° 51" 20'E longitude) across Kilivallithodu.

For the study of ichthyofauna diversity in the reservoir, fish were sampled bimonthly from 16 stations with the help of fishermen using gillnets during 2007-2010 (Fig. 1). The gillnets with mesh size of 14 mm and 26 mm (2m height, 100m length) were set close to the shore (depth < 3m) and nets of 40 mm mesh size (3.5m height, 100 m length) were set in the deeper part of the reservoir. Nets were set in late

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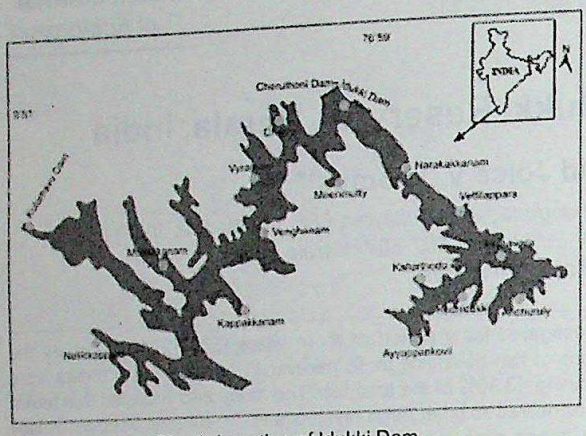


Fig. 1. Location of Idukki Dam

afternoon (17:00-19:00 hours) and retrieved the following morning (5:00-7:00 hours) in order to ensure a constant fishing effort. The collected specimens were counted and recorded total weight (g) before preserved in 10% formalin for further identification. The collected fish were brought to the laboratory and identified by using standard references such as Jhingran (1983), Talwar and Jhingran (1991), and Jayaram (1999).

RESULTS AND DISCUSSION

Species composition. A total number of 5800 fish, weighing 1266.76 kg were caught during the three years of study. In the present study, a total of 19 species of fish belonging to 18 genera, 11 families and 6 orders were recorded in the reservoir (Table 1). Cypriniformes, Siluriformes, Atheriniformes, Perciformes, Channiformes and Mastacembeliformes were the 6 orders and among these Siluriformes was represented by 4 families, Cypriniformes and Perciformes by 2 families each, whereas other orders were represented by a single family each. The family Cyprinidae was found to be the most diverse, represented by 9 species and the remaining families were represented by a single species each. Among the total number of fish collected during the study period, family Cyprinidae was dominated by contributing 43.36% of the total fish followed by Siluridae (20.05%), Cichlidae (7.62%), Channidae, (6.90%), Bagridae (5.22%), Mastacembelidae (4.88%), Cyprinodontidae (4.60%), Cobitidae (3.79%), Ambassidae (3.34%) whereas family Heteropneustidae and Clariidae contributed only 0.14% and 0.09%, respectively (Fig. 2).

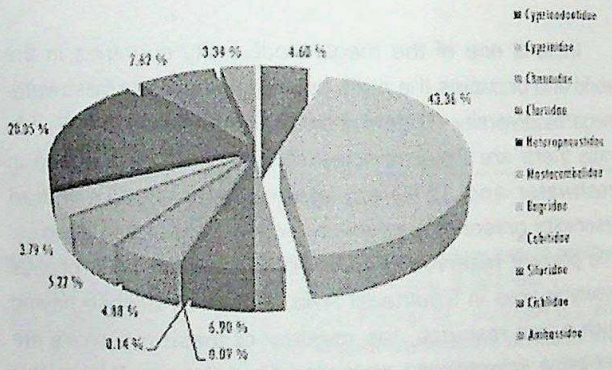


Fig. 2. Familywise percentage composition of fish abundance (total) from Idukki reservoir

Table 1. Fish species recorded from Idukki Reservoir

Order	Family	Species	Local Name
1.Cypriniformes	1.Cyprinidae	*1.Barilius bakeri*	Thuppalkothi
		2.Rasbora daniconius	Kallemutty
		3.Cirrhinus cirrhosa	Kooral
		4.Cyprinus carpio	Katti
		5.Catla catla	Catla
		6.Labeo rohita	Rohu
		7.Puntius melanampyx	Vazhakavarayan
		8.Puntius vittatus	Karingana/Kananjon
		9.Tor khudree	Yeru
2.Siluriformes	2.Cobitidae	*10.Nemacheilus rupecola*	Kalamparanda
	3.Bagridae	*11.Mystus vittatus*	Chillan Koori
	4.Siluridae	*12.Ompok bimaculatus*	Chottavala
	5.Clariidae	*13.Clarias batrachus*	Mushi
	6.Heteropneustidae	*14.Heteropneustis fossilis*	Kaari
3.Atheriniformes	7.Cyprinodontidae	*15.Aplocheilus lineatus*	Nettipotan
4.Perciformes	8.Cichlidae	*16.Oreochromis mossambicus*	Tilapia
	9.Ambassidae	*17.Parambassis dayi*	Chillumeen
5.Channiformes	10.Channidae	*18.Channa gachua*	Cherumeen
6.Mastacembeliformes	11.Mastacembelidae	*19.Mastacembelus guentheri*	Aaron

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The study conducted in the Idukki reservoir revealed that this reservoir had a moderate fish composition and diversity as compared to other large reservoirs in the country. The distribution of fish species was variable due to geographical and geological conditions of reservoir (Shaikh *et al.*, 2011). The physico-chemical factors also influenced the distribution, abundance and type of organisms of the reservoirs and these factors varied from region to region. Each reservoir had an individual capacity and production which also varied from one to another (Gundu, 2011). Piska *et al.* (2000) reported 28 species of fish belonging to four orders from Ibrahimbagh reservoir of Andra Pradesh. Sakhare (2001) recorded 23 species belonging to 7 orders in Jawalgaon reservoir, Maharashtra. Pawar *et al.* (2003) studied the fish diversity of Shirur dam (Maharashtra) and confirmed the occurrence of 11 fish species belonging to 5 orders. These studies agree that with 19 species under 18 genera, Idukki reservoir contains moderate fish production.

During the present study, family Cyprinidae recorded 43.36% of the fish recorded from this reservoir which is in agreement with the earlier findings of Gopinath and Jayachandran (1984) in Idukki reservoir. Several studies also denote that Cyprinidae family is dominated in other reservoirs of the country (Khedkar and Gynanath 2005; Battul *et al.*, 2007; Ubarhande *et al.*, 2011). The study conducted in certain reservoirs of Karnataka state also recorded more abundance from family Cyprinidae (Venkateshwarulu *et al.*, 2002; Wakid and Biswas, 2005; Thirumala *et al.*, 2011). The Idukki reservoir with the dominance of the family Cyprinidae denotes that it provides similar condition as other south Indian reservoirs for the growth of the fish, especially for cyprinids.

In Idukki reservoir, the exotic species like *Oreochromis mosambicus, Cyprinus carpio* and other Indian major carps were introduced by various authorities like Department of fisheries, Forest department and Panchayat bodies etc. without any specific plan and reason. There was no record on the recent introduction of the fish in this reservoir but in this study, the presence of *O. mosambicus* and *C. carpio* was noticed in reasonable quantities which indicated that the reservoir supported the growth of exotic species along with the indigenous species.

Abundance and biomass. The average number of fish (abundance) obtained from the reservoir during the study period showed that the species *Ompok bimaculatus* recorded the highest catch with the number of 387/year, followed by *Cirrhinus cirrhosa* with number 355/year and *O. mossambicus* with the average number of 148/year (Fig.3). The species *O. bimaculatus* also predominated as per relative abundance (20.05%) followed by *C. cirrhosa* (18.34%) and *O. mossambicus* (7.62%) (Fig.4). In Idukki reservoir, *Channa gachua* recorded the highest landings of 143.91 kg/year during the three years of study and it was followed by *Tor khudree* (81.66 kg/year) and *C. carpio* (Fig. 5). The relative biomass of *C. gachua*, *T. khudree* and *C. carpio* was 34.08%, 19.34% and 16.35%, respectively (Fig. 6).

According to Padmakumar *et al.* (2008), the main challenges in enhancing fish production are mainly the degradation of aquatic environment, increased competition for resources and inadequate institutional system. The low fish productivity of most of the reservoirs in Kerala is attributed to undesirable species mix, lack of scientific database, inadequate stocking, wrong selection of species and multiple ownership. The state electricity board has control over the reservoirs under hydro - electric project and those in the reserve forest are under the forest department. Fisheries department has access only to the irrigation reservoirs. This multiple ownership comes in the way of scientific management of reservoirs. The fish production in

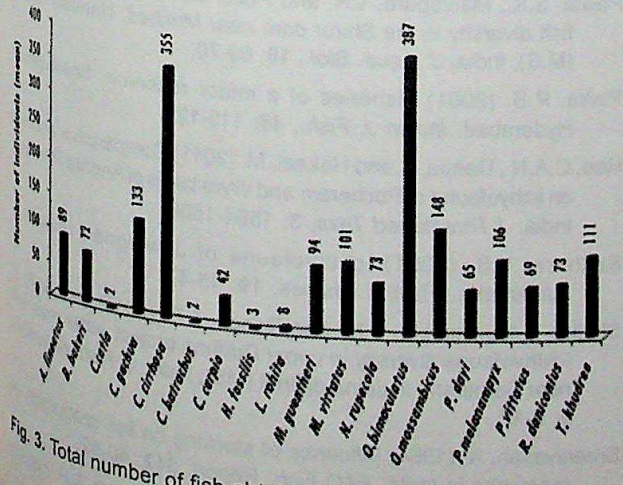


Fig. 3. Total number of fish obtained (mean) from Idukki reservoir

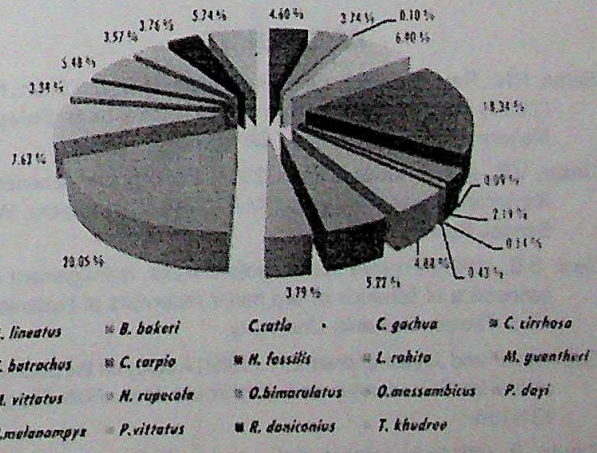


Fig. 4. Specieswise relative abundance of fish obtained (mean) from Idukki reservoir

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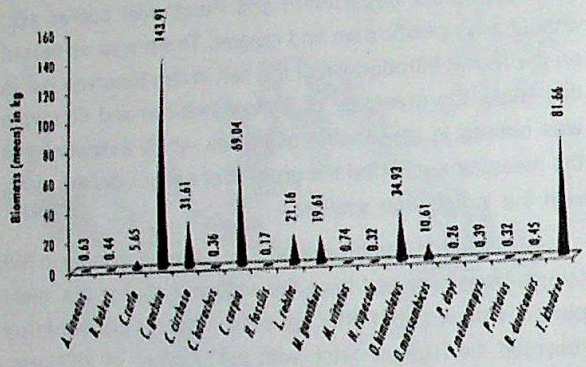


Fig. 5. Total biomass (mean) of fish recorded from Idukki reservoir

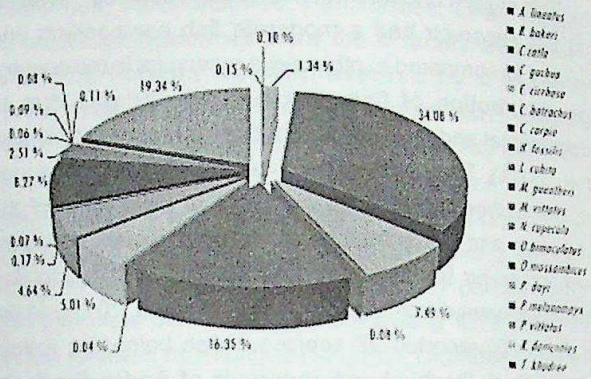


Fig. 6. Relative biomass of fish recorded from Idukki reservoir

Idukki reservoir clearly indicates that by proper and efficient management, this reservoir can be turned into an extremely productive one and can produce enviable spectrum of fish genetic resources leading to a many fold increase in inland fish production in the state. The quality of water free from any sort of pollution in Idukki reservoir also provides a favourable niche for fish production. Thus, by enhancing the fish production in Idukki reservoir, it can benefit to the tribal community development. Considering the immense potential of Idukki reservoir, there is a need for close co-ordination among the various stake holders and adoption of a holistic development approach to develop reservoir fisheries as suggested by Vass (2007).

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Indian Journal of Ecology

Optimization of Ethanolysis of *Jatropha* Oil to Produce Biodiesel and Characterization of its Fuel Properties

Monica Sachdeva Taggar*, S.K Singh[1], Rajesh Soni, Sarbjit Singh Sooch and M.K. Sangha[2]

School of Energy Studies for Agriculture,
[1]Department of Farm Machinery & Power Engineering,
College of Agricultural Engineering and Technology,
Punjab Agricultural University, Ludhiana-141004, Punjab (India)
[2]Department of Biochemistry, College of Basic Sciences and Humanities,
Punjab Agricultural University, Ludhiana-141004, Punjab (India)
**E-mail: monicasachdeva@pau.edu*

Abstract: Biodiesel is gaining increasing importance due to its less polluting and renewable nature as against the conventional diesel. In India, there are number of non-edible tree borne oilseeds with an annual production of more than 20 m t which have great potential for making biodiesel. Among these, *Jatropha curcas* L. oil has successfully proved its potential as substrate for biodiesel production. Transesterification is the most commonly used method for the conversion of oil or fat into biodiesel. The transesterification of *Jatropha* oil with anhydrous ethanol, using potassium hydroxide as a catalyst was studied. The pre-treatment of oil was carried out with 0.20 v/v ethanol to oil ratio in the presence of 1% H_2SO_4 as catalyst for 90 min. at 70°C. With this treatment, the free fatty acid content of the crude oil was reduced from 6.3% to <1% as measured by standard titrimetry method. The second step was the transesterification of treated oil using ethanol and potassium hydroxide as catalyst. The reaction conditions were optimized with respect to varying KOH concentrations, ethanol to oil molar ratio, reaction time and temperature of the reaction mixture. The maximum recovery of biodiesel (74%) was obtained with 10:1 molar ratio of ethanol to oil, 1.5% KOH catalyst, reaction temperature of 70°C and reaction time for 3 hrs. The produced biodiesel was characterized for the fuel properties such as viscosity, calorific value, flash point and density. The fuel properties were comparable to that of diesel.

Key words: Biodiesel, base-catalyzed transesterification, ethanol

The possibilities of a future fuel crisis and increasing awareness of health and environmental damage caused by burning the fossil fuels have motivated a lot of research on development of clean and renewable alternative energy sources (Payawan Jr *et al.*, 2010). Fossil fuels contribute to global warming by transferring previously sequestered carbon molecules into the atmosphere as CO_2, a greenhouse gas and a major source of air pollution through other combustion products found in the exhaust (Hanh *et al.*, 2010). Agriculture-based economies are putting their stake on biodiesel production from energy crops. The prices of fuels are rising day by day in India. Therefore, a large number of researchers have paid their attention since many years to produce oil substituted fuels. Biodiesel extracted from vegetable oils is an important renewable alternative and the researchers at Idaho have pioneered the use of such oils as diesel fuel substitute (Peterson *et al.*, 1990). Chemically, biodiesel is defined as an alkyl ester of long-chain fatty acids derived from renewable lipid sources (triglycerides). Biodiesel is environment-friendly, bio-degradable and produces significantly less amount of CO, SO_2, hydrocarbons, particulates and air toxic emissions than those of diesel (Hanh *et al*, 2010). The production of biodiesel would be cheap if the oil could be extracted from non-edible sources. *Jatropha curcas* (L.), a non-edible, oil bearing and drought hardy shrub is an important renewable and alternate source of biodiesel. However, the extracted oil can not be used directly in the diesel engine because of its high viscosity that reduces the fuel atomization and increases fuel penetration, thus responsible for high engine deposits and thickening of lubricating oil.

Base-catalyzed transesterification is most commonly used for large scale or commercial production because of its faster reaction rate and less corrosiveness as compared to acid-catalyzed process. The use of transesterified oil does not require any modification in the engine or injection system (Kywe and Oo, 2009). Moreover, the base-catalyzed transesterification of vegetable oil is usually carried out using methanol as reactant. Unfortunately, methanol is highly toxic and harmful to human health. The replacement of methanol with ethanol, which can be derived from renewable sources, can lead to environment friendly biodiesel production technology (Makareviciene and Janulis, 2003; Karabesko, 2009). The present work was, therefore, carried out to study the ethanolysis of *Jatropha* oil and the reaction conditions were optimized for enhanced

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recovery of biodiesel from oil. The biodiesel so produced, was characterized for various fuel properties.

MATERIAL AND METHODS

Jatropha oil was purchased from Rajasthan. The chemicals i.e. ethanol (anhydrous, 99.9%) and sulphuric acid were of analytical grade. The KOH pellets were used for base catalyzed trans-esterification.

Titrimetry method for determination of free fatty acid content. The free fatty acid content of crude oil is the key factor for determining the viability of base-catalyzed transesterification process. The free fatty acid content of oil was, thus, determined by titrimetric method (McKillican, 1966). To 1g of oil and 20ml benzene: alcohol (1:1), 1ml of phenolphthalein solution was added and titrated against N/40 NaOH. A blank determination without the addition of oil was also run with the above procedure.

Percentage of free fatty acid was calculated as (Oleic acid) = N (B-S) M/10W

where,

B= Volume of NaOH solution used for blank (ml)
S= Volume of sodium hydroxide used for oil (ml)
W=Weight of oil taken (g)
N= Normality of sodium hydroxide solution

Pre-treatment. The free fatty acids in crude oil were first converted into their esters in a pre-treatment process using sulphuric acid as catalyst. *Jatropha* oil free from water and contaminants was pre-heated at 70°C. Then, the solution of sulphuric acid and ethanol was added to the oil and stirred continuously maintaining a steady temperature of 70°C for required reaction time. The treated oil was then transferred in a separating funnel and the mixture was allowed to settle for 4hrs and the ethanol-water layer was removed. The free fatty acid content of separated oil was estimated by titrimetry method described as above. The effect of varying acid catalyst concentration, ethanol to oil ratio and reaction time on reduction in level of free fatty acid content of crude oil was determined.

Base-catalyzed Transesterification. The base-catalyzed transesterification was carried out in a round bottomed flask provided with a thermostat, mechanical stirrer and condensation system. The catalyst was first weighed in a vial and then dissolved in ethanol and the resulting mixture was then poured into flask containing pre-heated oil. The mixture was vigorously shaken at 300 rpm for the required reaction time. After the ethanolysis reaction was complete, the product was allowed to settle in a separating funnel for separation. The upper phase consists of ethyl esters and the lower phase contained glycerol and potassium salts. The prepared ester was washed and dried. The effects of various process parameters such as ethanol to oil molar ratio, reaction temperature, catalyst concentration and reaction time were studied to optimize the transesterification process for estimating the highest recovery of ethyl esters.

Fuel Properties. The prepared ethyl esters were characterized for important fuel properties viz., viscosity, density, calorific value, free fatty acid content and flash point. The viscosity of the biodiesel was measured using the viscosity measuring device 'VISGAGE'. A Pensky-Martens flash point (closed) apparatus was used for measuring the flash point of the ethyl esters. Bomb calorimeter was used to measure the gross heating value of the prepared biodiesel.

RESULTS AND DISCUSSION

Pre-treatment. The free fatty acid content of crude *Jatropha* oil was observed to be 6.3% as determined by standard titrimetry method (Table 1). This value was far above 1% limit for the transesterification reaction using alkaline catalyst. The pre-treatment process was carried out using sulphuric acid as catalyst to decrease the free fatty acid content to satisfactory limit. During pre-treatment studies, the effect of varying concentrations of acid catalyst, ethanol to oil ratio and reaction time on reduction in free fatty acid content of crude oil was studied. The increase in catalyst concentration (i.e. from 0.5 to 1.5% H_2SO_4) and ethanol to oil ratio (i.e. from 0.1 to 0.3% v/v) decreased the free fatty acid content to 1.0 and 1.2 per cent, respectively (Table 1 & 2). Similarly, an increase in the reaction time from 30 to 90 min significantly decreased the per cent free fatty acid content of oil to 0.9 per cent (Table 3). However, further increase in the reaction time (i.e.120 min) did not

Table 1. Effect of sulphuric acid concentration on free fatty acid content of pre-treated *Jatropha* oil*

Sulphuric acid conc. (%)	Volume of 0.1 N NaOH utilized (ml)	Free fatty acids (%)
Crude oil (untreated)	8.9	6.3
0.5	3.1	2.2
1.0	1.5	1.0
1.5	1.5	1.0

*Reaction time: 60 min; Reaction temp.: 70°C; Ethanol/oil ratio= 0.30 v/v; Stirring speed: 300 rpm

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Table 2. Effect of ethanol/oil ratio on free fatty acid content of pre-treated *Jatropha* oil*

Ethanol/oil ratio (v/v)	Volume of 0.1 N NaOH utilized (ml)	Free fatty acids (%)
Crude oil (untreated)	8.9	6.3
0.1	4.2	3.0
0.2	1.5	1.1
0.3	1.8	1.2

*Reaction time: 60 min; Reaction temp.: 70°C; Sulphuric acid 1%; Stirring speed: 300 rpm

Table 3. Effect of reaction time on free fatty acid content of pre-treated *Jatropha* oil*

Reaction time (min)	Volume of 0.1 N NaOH utilized (ml)	Free fatty acids (%)
Crude oil (untreated)	8.9	6.3
30	6.4	4.5
60	1.6	1.1
90	1.3	0.9
120	1.3	0.9

*Reaction temp.: 70°C; Sulphuric acid 1%; Stirring speed: 300 rpm; ethanol/oil ratio 0.20 v/v

show much effect on reduction in the free fatty acid content of oil. This may be probably due to water produced during the esterification of free fatty acid which further prevented the reaction (Ghadge and Raheman, 2006). Based on these studies, the optimum conditions chosen for the pre-treatment of crude oil were 1% H_2SO_4 catalyst, 0.2% v/v ethanol to oil ratio and 90 min reaction time.

Transesterification. The base-catalyzed transesterification was carried out using pre-treated oil that had <1% free fatty acid content. The effect of varying concentrations of KOH catalyst, ethanol to oil ratio, reaction time and temperature on per cent recovery of ethyl esters was studied. The maximum recovery of ethyl ester was reported to be 56.8-56.9 per cent with 1.5-2.0 per cent KOH catalyst concentration (Table 4).The per cent recovery of ethyl ester decreased by 2.3 fold with an increase in catalyst concentration from 2 to 3 per cent. The excess amount of catalyst may cause soap formation that may interfere with the reaction as well as with the separation of glycerol and thereby, significantly decrease the ester yield (Freedman *et al.*, 1984). A further increase in catalyst concentration leads to extra cost and therefore it is necessary to remove the catalyst from the reaction mixture after the reaction is completed.

The per cent recovery of ethyl esters increased with the increase in ethanol to oil ratio from 5:1 to 10:1 ratio. The maximum recovery of 74 per cent was obtained with 10:1 molar ratio of ethanol to oil for 3hrs reaction time (Table 5). The stoichiometry of transesterification reaction is usually 3:1 for alcohol to lipids. However, ethanolysis/methanolysis reaction is reversible and excess of alcohol is required to force the equilibrium to product side. Anastopoulos *et al.* (2009) studied the transesterification of vegetable oil with ethanol and during one stage process, the ester yield increased as molar ratio of ethanol to oil was increased with best yield of 85.4 per cent with molar ratio of 12:1. Freedman *et al.* (1986) and Schwad *et al.* (1987) studied the ethanolysis of sunflower oil and concluded that the excess of alcohol favored the conversion of di- to monoglycerides, but at higher concentrations, some recombination of glycerol and ester to monoglyceride may occur, thus lowering the overall yield of esters.

The per cent recovery of ethyl esters increased with increase in temperature of reaction mixture (Table 6). The

Table 4. Effect of varying KOH concentrations on per cent recovery of *Jatropha* oil ethyl ester*

KOH conc. (%)	% Recovery			Mean (%)
	I Run	II Run	III Run	
1.0	55.2	55.4	53.6	54.7
1.5	58.0	56.0	56.5	56.8
2.0	58.0	56.0	56.7	56.9
2.5	40.0	40.8	41.0	40.6
3.0	25.0	24.0	24.5	24.5

*Preheating time: 10 min, Reaction time: 2 hrs, Reaction temperature: 70°C, ethanol/oil molar ratio= 6:1, Stirring speed: 300 rpm, Settling time: 72 hrs.

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Table 5. Effect of varying ethanol/oil ratio and reaction time on per cent recovery of *Jatropha* oil ethyl ester*

Ethanol /oil molar ratio	Reaction time (hrs)	% Recovery			Mean (%)
		I Run	II Run	III Run	
5:1	2	-	-	-	
6:1	2	58.0	56.2	56.0	56.7
8:1	2	60.5	58.0	62.3	60.3
8:1	3	63.2	65.0	67.5	65.2
9:1	2	68.0	67.2	69.1	68.1
10:1	2	69.0	73.0	70.0	70.7
10:1	3	72.0	74.0	75.5	73.8

*Preheating time: 10 min, Reaction temperature: 70°C, Catalyst conc. (KOH):1.5%, Stirring speed: 300 rpm, Settling time: 72 hrs

Table 6. Effect of varying temperature on per cent recovery of *Jatropha* oil ethyl ester*

Temperature (°C)	% Recovery			Mean (%)
	I Run	II Run	III Run	
65	63.0	67.0	65.0	65.0
70	73.0	74.8	72.0	73.3
75	75.0	72.0	70.0	72.3

*Preheating time: 10 min, Reaction time: 3 hrs, Oil/ethanol molar ratio= 10:1, Stirring speed: 300 rpm, Settling time: 72 hrs

Table 7. Fuel Properties of Jatropha oil and its ethyl esters

Fuel properties	*Jatropha* oil	*Jatropha* oil ethyl ester	Diesel	ASTMD6751
Density (g/ml)	0.93	0.86	0.84	0.87-0.89
Free fatty acids (%)	6.2	0.25	-	-
Viscosity (cSt)	38.0	6.1	4.5	1.9-6.0
Calorific value (MJ/Kg)	37.9	41.3	42.0	-
Flash point	287.3	113.0	58.3	>130

ethyl ester recovery was only 65 per cent at 65°C and it reached to 73.3 per cent at 70°C temperature during the same reaction time. The increased temperature may affect the miscibility of ethanol with triglycerides and thus improves the ester yield. The fuel properties of prepared biodiesel were studied and corresponded to the standard limits (Table 7).

To conclude, the higher free fatty acid content (6.3%) of crude *Jatropha* oil was reduced to <1% in a pre-treatment process using acid catalyzed reaction (1% v/v H_2SO_4) with ethanol (0.20% v/v) at 70°C temperature and 90 min reaction time. The base-catalyzed transesterification i.e. 1.5% KOH, 10:1 molar ratio of ethanol/ oil, reaction temperature 70°C and reaction time 3 hrs yielded 74% recovery of biodiesel.

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Effect of Sowing Dates and Varieties on Yield and Quality of Garden Pea Seed

Parveen Sharma* and Dalveer Singh Khyalia

Department of Vegetable Science and Floriculture
CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176062
**E-mail: dr.sharma69@rediffmail.com*

Abstract: A trial on effect of sowing dates and varieties on seed yield and quality of garden pea was conducted at CSK HPKV, Research Sub Station Akrot during rabi, 2007-2008. Pea seeds of four varieties viz., Matar Ageta, Arkel, Lincoln and Palam Priya were sown on 7th November and 21st November. Early sown crop resulted in significantly higher seed yield (12.6 q/ha) than the late sown crop (11.4 q/ha). Among the varieties studied, Palam Priya and Lincoln were statistically at par and gave significantly higher seed yield (13.5 and 13.1 q/ha, respectively) over rest of the cultivars. Sowing time and varieties interacted significantly for seed yield per plant.

Key Words: Pea yield, quality and sowing date

In the past, several high yielding varieties of early, mid and late maturity groups have been developed, but very little emphasis has been given for agronomic practices to exploit the genotypic worth of the crop for obtaining maximum returns per unit area and time. Planting time is the most critical factor influencing the plant growth and maturity in peas, particularly in hills which experience different meteorological regimes during a single season. Fluctuation of temperature during germination enhances plant mortality due to desiccation, while plants flower early on account of higher temperature contributing to poor yield (Singh and Singh, 1995).Meanwhile, crops subjected to freezing temperatures and severe occasional frost during winters, may also hamper seed set resulting in low seed yield (Singh *et al.*, 1996). Thus, it may be desirable to have an appropriate balance between the length of vegetative and reproductive phases and to restrict the vegetative growth to an optimum level to secure enhanced production. Garden pea cultivars are successfully grown in different pockets of the state. And there is acute dearth of quality seed of garden pea. The land holding in Himachal Pradesh is small and fragmented, which necessitates growing of profitable seed and fresh high value crop like garden pea. The seed yield of different garden pea cultivars is quite low and need to be enhanced by standardization of various agro-techniques. The present study was thus conducted to underline the optimum sowing time for low hills of Himachal Pradesh for popular vegetable pea varieties.

MATERIAL AND METHODS

The present investigations were carried out at the Experimental Farm of the CSK Himachal Pradesh Krishi Vishvavidyalaya, Research Sub Station Akrot (Una). The place is characterized by severe summers and mild winters with moderate rainfall Agro-climatically, the location represents low-hills of Himachal Pradesh and is characterized by sub–tropical zone with moderate rainfall (1200 mm). Soil of the experimental area was sandy loam in texture and neutral in reaction and also low in nitrogen and potash and high in phosphorus contents. The experiment was laid in factorial randomized block design with two dates of plantings i.e. 7th November and 21st November and four cultivars viz., Mater Ageta,Palam Priya, Arkel and Lincoln .Besides the application of farm yard manure (FYM) @ 20t ha^{-1}, the chemical fertilizers were applied as per recommended package of practices (50 kg N, 60 Kg P_2O_5 and 60 kg K_2O ha^{-1}). The recommended package of practices was followed for raising the crop. Observations on the characters *viz.*, days to 50% flowering, days to 50% marketable maturity, plant height (cm), days to seed harvest, number of pods per plant, pod length (cm), number of seeds per pod, seed yield per plant (g), seed yield per hectare (q/ha), 100-seed weight (g), seed germination (%) and seed vigour were recorded. The observations were recorded on ten competitive plants, taken at random, in each entry and replication. For the characters *viz.*, 100-seed weight, seed germination (%) and seed vigor a random sample of seed per entry per replication were drawn.

RESULTS AND DISCUSSION

Effect of sowing dates

Days taken to 50% flowering significantly varied owing to planting dates (Table 1) crop planted on 21st November took significantly less number of days as compared to 7th November planting. The fifteen days difference in sowing dates was narrowed down to three days for days to 50% flowering. This may be due to more favourable temperature

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Table 1. Effect of sowing dates and varieties on seed production of garden pea

Treatments	Days to flowering	Days to marketable maturity	Plant height (cm)	Days to seed harvest	Pods/ plant	Pod length (cm)	Seeds/ pod	Seed yield/ plant (g)	Seed yield/ ha (q)	100-seed weight (g)	Seed germination (%)	Seedling length (cm)	Seed vigour
Sowing Dates:													
7th November	73.7	82.7	68.2	137.4	10.3	7.9	6.4	10.8	12.6	18.6	95.8	19.0	1815.2
21st November	70.9	80.7	66.0	135.3	9.9	7.7	5.9	9.8	11.4	18.5	95.6	18.7	1785.0
CD (p=0.05)	0.5	0.4	0.9	1.9	0.5	NS	0.1	0.9	0.5	NS	NS	0.3	28.8
Varieties :													
Matar Ageta	61.7	74.3	59.1	131.6	5.8	6.6	4.6	8.5	10.5	19.5	95.6	17.6	1680.4
Arkel	70.5	78.3	63.6	134.5	8.6	7.8	6.3	10.2	10.8	14.8	95.7	16.8	1596.9
Lincoln	78.3	86.3	72.4	139.3	10.3	8.2	6.4	11.1	13.1	16.0	95.4	18.6	1784.5
Palam Priya	78.6	87.7	73.2	139.9	15.7	8.6	7.5	11.4	13.5	20.1	95.9	22.4	2138.5
CD (p=0.05)	0.5	0.5	2.3	1.5	0.3	0.2	0.4	0.5	0.4	0.4	NS	0.1	24.7

for flowering under late sown conditions. Early flowering with delayed sowing has also been reported by Gritton and Ebert (1975); Mehla *et al.* (1997). Similarly planting dates exhibited significant variation for days to 50% marketable maturity. Crop planted on 21st November took significantly less number of days to 50% marketable maturity than planting on 7th November. The days taken to 50% marketable maturity were further narrowed down to two days. Since the temperature was optimum during the early sowings than late, this might have attributed for attaining growth and development of the plants. Plant height was significantly affected by planting dates. Maximum plant height was obtained with early planting which subsequently declined with successive delays. In the present investigations, the initial moderate temperature for early sown crop favoured optimum plant growth as compared to low temperature during second planting. Therefore, a decline in plant height was observed in 21st November planting in comparison to 7th November planting. The influence of favourable weather conditions to attain increased plant height has also been reported by various workers (Chatterjee *et al.*, 1991; Sharma *et al.*, 1997). Planting dates played a prominent role on days to seed harvest (Table 1). Earlier planting (7th November) significantly delayed the harvesting of seeds as compared to 21st November planting. Numbers of pods per plant were appreciably more in case of crop planted on 7th November. This might be due to the fact that the early sown crop had the advantage of prolonged and full season of growth and better atmospheric conditions. Moreover, taller plants obtained with early sowing could possibly accommodate more number of pods per plant. Less number of pods obtained with late sowing may be attributed to unfavourable weather factors i.e. comparatively higher average temperature at flowering and pod setting stages from mid February onward. These results are in close conformity with those of, Chatterjee *et al.* (1991), Batra *et al.* (1992) and Singh and Singh (1995).

Seeds per pod were significantly higher in case of early planting (7th November) as compared to late planting (21st November). However, planting dates did not differ significantly in influencing pod length, 100-seed weight and percent germination. The seed yield was significantly higher during first date of planting (7th November) than the second date of planting by (21st November). Yield in pea is influenced by various contributing characters (Kumar, 1994), of which number of pods and seed yield per plant outplayed other characters in the present investigations. Increased yield for early planted crop might be attributed to relatively longer optimum period available for crop growth. The present findings are in consonance with Singh and Singh (1995)

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and Mehla *et al.* (1997), who reported reduced grain yield due to poor vegetative growth and yield attributes as a result of higher temperature. Favourable weather conditions during crop growth period to produce higher yield has also been reported by various researchers (Chatterjee *et al.*, 1991; Batra *et al.*, 1992; Singh and Singh, 2011).

Seed vigour is an important parameter which determines the actual germinability of seed under field conditions. Shukla and Kohli (1992) reported higher seed vigour as highly desirable to obtain uniform plant stand especially under stress conditions. During the present study, seeds sown on earlier date (7th November) exhibited higher vigour, which may be attributed to favourable conditions for seed development and ripening than second date of sowing (21st November). The results confirm the findings of Castillo *et al.* (1994), who reported that varied time of sowing did affect the seed vigour.

Effect of varieties

Out of the four cultivars studied Matar Ageta was found to be earliest in flowering, marketable maturity and days to seed harvest (Table 2). This may be due to the reason that a strain of early pea is capable of giving better plant stand at relatively high temperature. Similar results of varietal variation for flowering and maturity have also been reported by Singh *et al.*, 1996. Maximum plant height was recorded in cvs. Palam Priya and Lincoln and minimum for cv. Matar Ageta. Cultivars Matar Ageta and Arkel recorded minimum plant height because of their dwarf nature. The time of harvesting is also a varietal character. The cultivars Matar Ageta and Arkel proved to be earlier than cvs. Linclon and Palam Priya with respect to seed harvest. Varietal variation with regards to number of pods per plant was observed and cultivar Palam Priya proved to be the best, which could be attributed to its superior genetic potential. Besides, Palam Priya being taller cultivar than others accounted increased pod number. Differential behaviour of varieties with respect to pods per plant has also been reported by various workers (Mehla *et al.*, 1997). Among different cultivars, Palam Priya registered longer pods. Cultivar Palam Priya has also been observed superior than other cultivars for number of seeds per pod. Higher pod length observed for Palam Priya accounted for increased seeds per pod. Varietal differences with respect to seeds per pod have also been reported by Mehla *et al.* (1997). Significant variation among cultivars with regard to yield per plant and per hectare was observed and Palam Priya out yielded other cultivars, which might be due to its inherent potential, as it proved superior for all yield contributing characters studied. Significant varietal variation with respect to seed yield has also been reported by different workers (Singh *et al.*, 1991; Singh and Singh, 1995; Mehla *et al.*, 1997). The superiority of cultivar Palam Priya for seed weight may be attributed to its genetic potential. There were no significant differences in seed germination in different cultivars. Seed vigour varied significantly among different cultivars. Palam Priya showed highest seed vigour as compared to other cultivars whereas significantly lowest seed vigour was in cultivar Arkel. Similarly.

Table 2. Interaction effect between planting dates and cultivars on seed yield per plant (g)

Planting dates	Cultivars			
	Matar Ageta	Arkel	Lincoln	Palam Priya
7th November	9.9	10.5	11.2	11.5
21st November	7.2	9.8	11.0	11.3

To compare cultivars at same planting dates CD (p=0.05) = 0.7
To compare planting dates at same or different cultivars CD (p=0.05) = 1.1

Interaction between sowing dates and cultivars

The interaction effect of sowing dates and varieties was significant for days to 50% flowering (Table 3). Cultivar Matar Ageta took minimum number of days to 50% flowering irrespective of planting dates followed by Arkel whereas Lincoln and Palam Priya were statistically at par with respect to days to 50% flowering at each date of planting.

Planting time and cultivars interacted significantly for seed yield per plant (Table 3). Early planting (7th November) of Matar Ageta was superior to late planting (21st November) for seed yield per plant. At each dates of planting, Palam Priya remaining at par with Lincoln, resulted in significantly higher seed yield per plant. However, Lincoln was at par with Arkel in November 7th planting. Matar Ageta sown on 21st November resulted in significantly lowest seed yield per plant.

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Indian Journal of Ecology

Effect of Different Dates of Transplanting on the Microclimate and Biometric Parameters of Brinjal (*Solanum melongena* L.)

Amandeep Kaur* and Som Pal Singh

Department of Agricultural Meteorology
Punjab Agricultural University, Ludhiana-141004, India
**E-mail: aman_586@yahoo.com*

Abstract: A field experiment was planned to investigate the effect of different types of dates transplanting on microclimate of brinjal, at the Research Farm, Department of Agricultural Meteorology, Punjab Agricultural University, Ludhiana during the *Rabi* season 2008-09. The transplanting was done on three different dates (DOT) *viz.* 11th November (D_1), 29th November (D_2) and 9th December (D_3). Among the dates of transplanting the micrometeorological parameters were more favorable for growth, yield and development of brinjal crop transplanted on 11th Nov. followed by 29th Nov. and 9th Dec. The wind speed was more in D_3 as compared to D_2 and was followed by D_1. The wind velocity ranged from 4.50 to 6.68 Km/hr in D_3, 3.20 to 6.46 Km/hr in D_2 and 3.00 to 6.18 Km/hr in D_1. Simillarly crop transplanted on D_3 recorded the highest canopy temperature at all the stage of observation followed by D_2 and D_1. The evaporation in the crop differed significantly with the dates of transplanting. The evaporation was recorded higher in D_3 (0.44-9mm/day) followed by D_2 (0.39-8.4mm/day) and D_1 (0.21-8.23mm/day). Date of transplanting significantly affected the solar radiation interception of brinjal. Among three dates of transplanting, crop transplanted D_1 recorded the highest photosynthetically active radiation interception, plant height and LAI (leaf area index) at all the stages of observation followed by D_2 and D_3.

Key Words: Brinjal, microclimate , DOT , LAI and plant height

Vegetables are essential food supplements in human diet which provide various minerals, vitamins and protective elements which enhance the immune system. Some times the slight variability in the weather may destroy the crops in terms of quality and quantity. Potential productivity of a crop in a region is determined by climatic factors which are called as macroclimate but the responses of plants in a crop canopy is also influenced by the immediate microclimate extending from the top of the crop or tree canopy to the lowest layer of roots. In the recent past, a lot of region specific variability has been observed in the weather and climate in different parts of the earth like drought, rain havoc, frost, high wind velocity and hot waves. This variability lead to reduction in crop yield in terms of both quality and quantity. To optimize such harsh environmental calamities, successful agriculture requires sure knowledge of physiology of plants and their response to the environmental factors. Brinjal requires a long and warm growing season and is sensitive to frost injury. Chilling weather for longer time damages the crop. A temperature in the range of 20-30°C is most favourable for its successful production (Anonymous 2008). A well drained and fertile soil is desirable for growing brinjal. However to raise an early crop, sandy or sandy loam soil is preferred with pH 5.5-6.6. In Northern India it is sown during June-July as an autumn winter crop and in November for spring summer crop (Chanda 2003). Even a little variation in the microclimate at critical stages of the crop growth can lead to significant differences in plant growth, fruit set and consequently economic returns. Agriculture will need to be progressively adapted to future climate and research system should be oriented to monitor and evaluate climate change and develop adaptive technologies for sustainable crop production with changes in agricultural practices such as manipulation of dates of sowing, row orientations to increase or reduce the radiation, heat or input use efficiencies, plant spacing etc. Irrigation moderates soil temperature by increasing evaporative cooling, soil specific heat and heat flow into soil due to enhanced thermal conductivity. The extent and duration of this effect, however, depends on solar radiation flux, nature and extent of vegetative cover, thermal properties of soils and the amount and temperature of irrigation water applied. Sharma and Koul (2004) observed that the different planting dates resulted in significant variations among different horticultural trails which had significant effect on yield. Khobragade *et al* (2008) studied the influence of radiation use efficiency in mustard as influenced by different sowing dates, plant spacing and genotypes and the result showed that the highest seed yield of 1414.43 kg/ha was obtained in first date of sowing on 6th Nov and lowest of 866.52 kg/ha in 27th Nov sown crop. Thus an early sown crop is expected to out yield a late sown crop (Biscoe & Gallagher, 1978; Monteith, 1981; Khan, 2000).

MATERIAL AND METHODS

The field experiment was conducted at the Research Farm, Department of Agricultural Meteorology, Punjab Agricultural University Ludhiana during the *Rabi* season

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2008-09. The treatments consisted of three types of dates of transplanting i.e 11th November (D_1), 29th November (D_2) and 9th December (D_3) replicated three times and subjected to analysis of variance in Split Plot Design. Plant height was recorded from the 5 plants tagged at random in each plot at 15 days interval starting from 30 days after transplanting. The height was measured from the ground surface to the base of the upper fully developed leaf. Photosynthetically Active Radiation (PAR) The incoming and outgoing photosynthetically active radiation (PAR) on the top of the crop canopy and their penetration within the canopy and at the bottom of the crop canopy were measured with a line Quatum sensor (Model LI-190 SB) to work out interception percentage. PAR in the range of 400-700nm. These observations were taken from 8:30 to 16:30 hrs at 2 hrs intervals on a clear day. The per cent interception was calculated as under:

$$\text{Percent interception} = \frac{\text{PAR (I)} - \text{PAR (T)} - \text{PAR (R)}}{\text{PAR (I)}} \times 100$$

Where

PAR (I) = PAR incoming above the canopy
PAR (T) = PAR transmitted to the ground
PAR (R) = PAR reflected from the canopy

Canopy temperature was measured with the help of an Infra Red thermometer (Everest 574-NI). The infra red thermometer was held at an angle of 45° one meter above the canopy. The canopy temperature was recorded at 1430 hr. The observations were recorded at 15 days interval when the crop canopy was fully developed. Leaf area index was measured with plant canopy analyzer (LAI 2000 (LICOR, US).The observations on leaf area index were taken at 15 days interval from 5 different sites in each plots for more accuracy by placing the sensor onces above the crop canopy followed by placing it below the crop canopy diagonally across the rows. Wind speed was recorded at 4H distance for 3 minutes at 11.00 a.m from the shelterbelt above the canopy on leeward side and also from control plots using the portable Biram anemometer. The plastic cans of uniform diameter of 15 cm depth filled with water were kept at 1 H from the wind break on leeward side in the experiment and also in open plots. Evaporation was measured with the scale.

RESULTS AND DISCUSSION

Wind speed

Wind is an important weather element and both its direction and velocity are significant. It influences plant life, both mechanically and physiologically. Wind speed was recorded in the crop canopy at 15 days interval starting from 15 days after transplanting upto 120 DAT. Non significant differences in the wind speed was obtained with respect to dates of transplanting. However the wind speed was more in D_3 as compared to D_2 and was followed by D_1. The wind velocity ranged from 4.50 to 6.68 Km/hr in D_3, 3.20 to 6.46 Km/hr in D_2 and 3.00 to 6.18 Km/hr in D_1 This may be due to the reason that the performance of crop was not as good as in the other two dates of sowing. Thereby the canopy was sparce and movement of the wind was not obstructed in this date of sowing (D_3) than D_1 and D_2 (Table 1).

Evaporation

Evaporation is the resultant of air temperature, wind-speed and relative humidity along with the amelioration in these microclimatic factors. The evaporation was recorded when the crop was 50 days old and developed sufficient amount of biomass. These observations were continued up to the maturity of the crop. The evaporation in the crop differed significantly with the dates of transplanting. The evaporation was recorded higher in D_3 (0.44-9mm/day) followed by D_2 (0.39-8.4mm/day) and D_1 (0.21-8.23mm/day) (Table 2).

PAR interception

Periodic data pertaining to photosynthetically active radiation interception was recorded during vegetative phase, flowering phase, reproductive phase, and at maturity. Date of transplanting significantly affected the solar radiation interception of brinjal. Among three dates of transplanting, crop transplanted on 11th November (D_1) recorded the highest photosynthetically active radiation interception at all the stages of observation followed by 25th November (D_2) and 9th December (D_3) (Fig. 1) However, it was reduced significantly when transplanting was delayed.

Table 1. Wind speed (Km/hr) as influenced by dates of transplanting in brinjal.

	Days after transplanting							
	15	30	45	60	75	90	105	120
Dates of transplanting								
D_1 (11th Nov.)	3.00	3.97	5.94	4.57	6.18	6.05	4.32	3.89
D_2 (25th Nov.)	3.20	3.98	5.98	4.83	6.46	6.07	4.91	4.09
D_3 (9th Dec.)	4.50	4.12	6.28	4.95	6.68	6.33	5.52	4.87
C.D. (P=0.05)	0.57	NS	NS	NS	NS	NS	0.31	0.43

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Table 2. Evaporation (mm/day) as influenced by dates of transplanting in brinjal.

Treatment	Days after transplanting										
	50	57	64	71	78	85	92	99	106	113	120
Dates of transplanting											
(11th Nov.)	0.27	0.71	0.21	1.19	1.13	2.20	2.10	2.19	3.48	2.09	3.31
D_2 (25th Nov.)	0.39	1.14	1.4	1.39	2.09	2.66	2.31	2.53	4.43	2.59	4.19
D_3 (9th Dec.)	0.44	1.85	1.54	1.56	2.45	2.58	2.64	3.02	4.75	4.48	5.96
C.D. (5%)	0.09	0.37	0.68	0.18	0.31	0.29	0.17	0.24	0.27	0.41	0.71

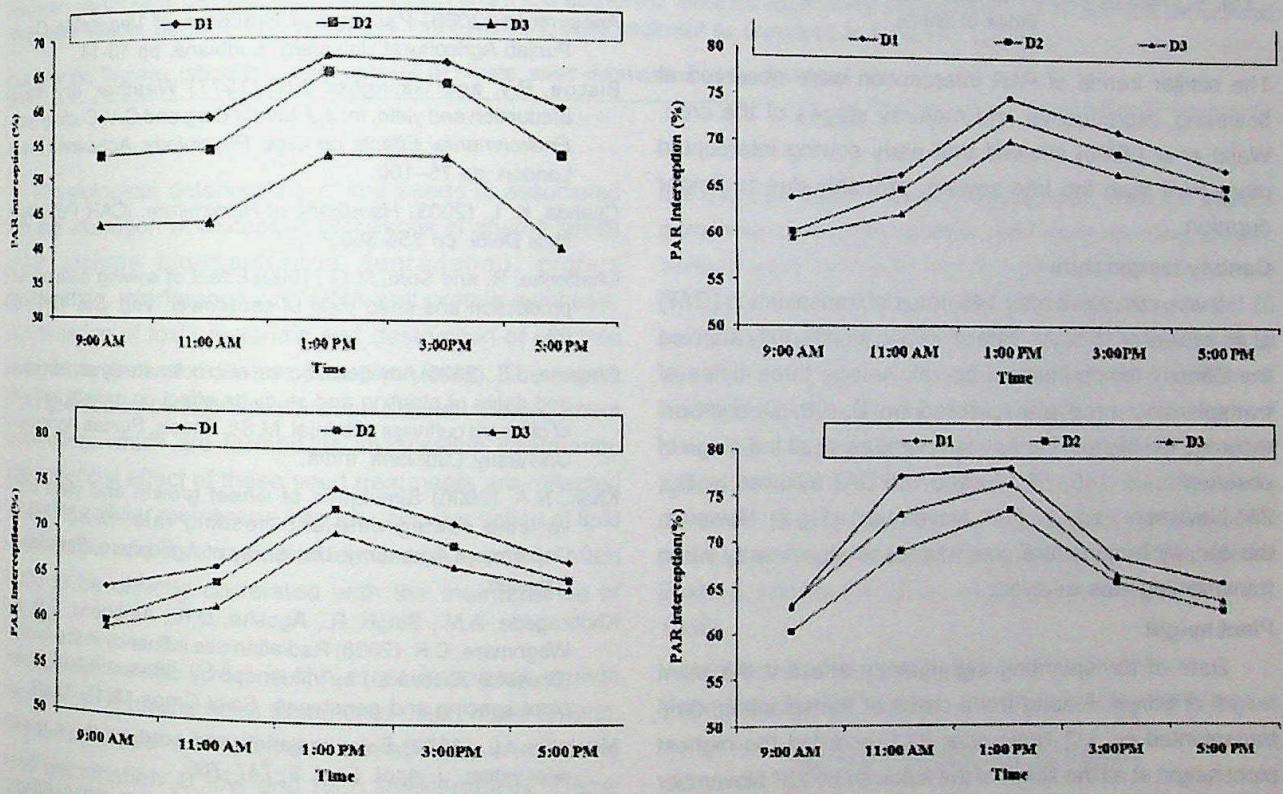


Fig. 1. Effect of different dates of transplanting on photosynthetically active radiation during (a) vegetative, (b) flowering, (c) reproductive and (d) at maturity phase.

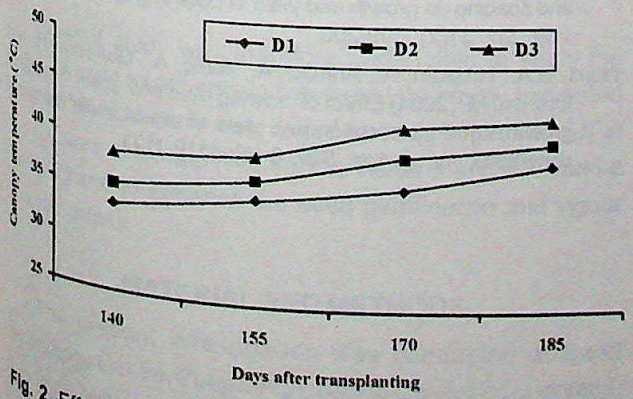


Fig. 2. Effect of different dates of transplanting on variability of canopy temperature

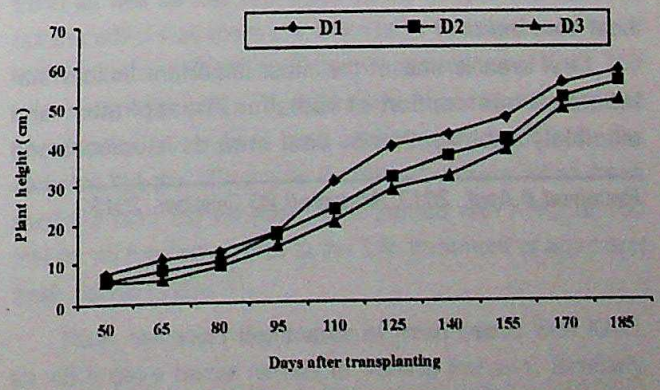


Fig. 3. Effect of different dates of transplanting on plant height of brinjal

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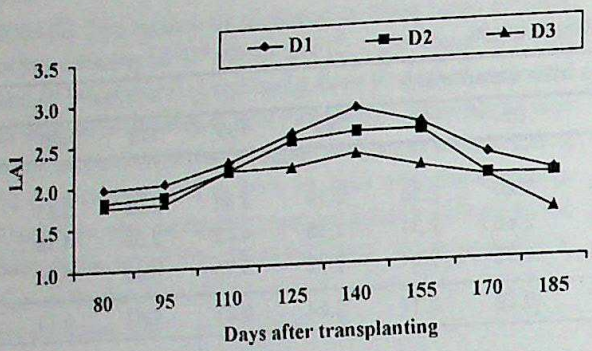


Fig. 4. Effect of different dates of transplanting on leaf area index of brinjal

The similar trends of PAR interception were observed at flowering, reproductive and maturity stages of the crop. Wajid *et al* (2004) showed that early sowing intercepted more PAR than the late sowing, probably due to longer duration.

Canopy temperature

It was measured after 145 dates of transplanting (DAT) at an interval of 15 days. Date of sowing significantly affected the Canopy temperature of brinjal. Among three dates of transplanting, crop transplanted on D_3 (9th December) recorded the highest canopy temperature at all the stage of observation i.e. 145,155,170 and 185 DAT followed by D_2 (25th November) and D_1 (11th November) (Fig.2) However, the canopy temperature was increased significantly when transplanting was delayed.

Plant height

Date of transplanting significantly affected the plant height of brinjal. Among three dates of transplanting, crop transplanted on 11th November (D_1) recorded the highest plant height at all the stage of the followed by 25th November (D_2) and 9th December (D_3) (Fig. 3).Singh *et al* (2010) observed a linear decline in the plant height with delay in sowing. They further reported that with delay in sowing, the flowering and maturity periods were reduced in all the genotypes.

Leaf area index

Leaf area is one of the most important factors that influence interception of radiation, transpiration and ultimately photosynthesis. Leaf area development and maintenance are considered to be a key factor for maximum dry matter production. Change in the environmental production factors during the active period of the growth is believed to be one of the main causes for the variation in the yield. Crop transplanted on 11th November (D_1) recorded the Highest LAI which coincided with 140 DAT followed by 25th November (D_2) and 9th December (D_3) (Fig. 4). Similar results were reported by Cheema (2005) in brinjal and Chatterjee and Som (1990) in cauliflower.

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Indian Journal of Ecology

Effect of Seed Treatments on Germination and Vigour Parameters in Seeds of Tomato (*Lycopersicon esculentum* Mill.)

Namarta Gupta and Chinka Batra

Department of Botany, Punjab Agricultural University, Ludhiana-141 004, India
**E-mail: namjindal70@yahoo.co.in*

Abstract: The influence of seed treatments (Hydration, KNO_3, GA_3) on the seed germination and vigour parameters of tomato (*Lycopersicon esculentum* L.) varieties (Varkha Bahar-1 and Varkha Bahar-2) for 24 and 48 h in fresh and aged seeds was observed. Seed treatments increased percentage germination, vigour index I and II and decreased electrical conductivity. Varkha Bahar-1 showed more pronounced effect than Varkha Bahar-2. The effect was more with GA_3 seed treatment as compared to KNO_3 and hydration.

Key Words: Tomato, gibberellic acid, potassium nitrate, seed germination and seed vigour.

Physiological deterioration of the seeds is associated with the alteration of metabolic processes in ageing seeds which include bio-membrane degradation, protein denaturation, interference with DNA and protein synthesis, accumulation of toxic materials and destruction of electron transport system of oxidative phosphorylation. The vigour of the seed could be activated through extrinsic management techniques, which are termed as invigoration treatments. The beneficial effect of these seed treatments are reflected in greater cellular membrane integrity, counter action of lipid peroxidation and free radical chain reaction and is often found to be directly correlated with the maintenance of viability.

Gibberlic acid (GA_3) is the most important growth regulator. Pre-sowing seed treatments using moist-chilling, GA_3 and salts such as KNO_3 had been affective in improving seed germination at low and high temperatures (Demir and Mavi 2004). Pre-sowing seed treatment on seed lots of tomato, capsicum and onion with different concentrations of GA_3, kinetin, PEG, and mannitol caused an increase in hypocotyl length in fields as compared to untreated seeds (Jagadish *et al* 2004).

Present study was therefore undertaken to study the effect of seed treatments in two seed lots freshly harvested (May 2010) and carry over /aged seed (14 months old) in two cultivars of tomato (Pb. Varkha Bahar-1 and Pb. Varkha Bahar-2) and to enhance the seed germination and vigour of aged seeds.

MATERIAL AND METHODS

The present investigation was conducted at Seed Technology Centre, Punjab Agricultural University, Ludhiana. Seeds of two cultivars of tomato (*Lycopersicon esculentum* L.) Varkha Bahar-1 and Varkha Bahar-2 were procured from the Director Seeds, PAU, Ludhiana and used for studies pertaining to seed germination and early seedling growth. Various seed treatments *viz* Hydration, potassium nitrate (KNO_3 50 and 150 mM), gibberellic acid(GA_3 10 ppm and 20 ppm) were given for 24 and 48 h to both fresh as well as aged seeds at 25°C. After seed treatments with different solutions, seedlings were raised between the two layers of germination paper kept in the seed germinator at temperature 25±2°C for 14 days. Effect of seed treatments on seed quality of tomato was evaluated by seed germination percentage (ISTA 2008), vigour index (Abdul Baki's & Anderson (1973) , electrical conductivity (Presley 1958).

Vigour Index I = Germination (%) x Seedling length (cm)

Vigour Index II = Germination (%) x Seedling dry weight (mg).

RESULTS AND DISCUSSION

Percent germination

Varkha Bahar-1 has more percent germination than Varkha Bahar-2 in control conditions. The hydration of seeds for 24 h and 48 h increased the percent germination in fresh as well as naturally aged seeds of both the varieties but the effect was more pronounced in Varkha Bahar-1, in 48 h hydration at 25°C. Both the concentrations of KNO_3 (50 mM and 150 mM) significantly increased percent germination in fresh as well as aged seeds of both the varieties but the effect was found to be more when fresh seeds of both the varieties were treated with KNO_3 at 150 mM for 48 h as compared to the 24h treatment of aged and fresh seeds (Table 1).

Thus, the seed treatments of fresh seeds with KNO_3 for 48 h gave better results in Varkha Bahar-1. Similarly, both the concentrations of GA_3 (10 ppm and 20 ppm) significantly increased the percent germination (89.5 by 10

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Table 1. Effect of seed treatments on percentage germination of seedlings of fresh and aged seeds of tomato (*Lycopersicon esculentum* L.)

Treatments	Varkha Bahar-1				Varkha Bahar-2			
	24 h		48 h		24 h		48 h	
	Fresh	Aged	Fresh	Aged	Fresh	Aged	Fresh	Aged
Control	79.5	75.2	79.5	75.2	76.0	70.5	76.0	70.5
Hydration	81.0	76.5	83.6	78.0	78.5	72.0	81.0	74.5
KNO_3(50mM)	83.0	78.5	86.5	81.5	81.0	74.5	83.5	79.0
KNO_3(150mM)	85.5	81.5	89.5	83.0	84.7	78.2	85.6	81.2
GA_3 (10ppm)	89.5	83.5	93.0	85.5	86.6	81.5	88.2	83.1
GA_3 (20ppm)	92.5	85.0	95.0	88.5	89.5	83.5	91.5	85.0
CD at 5%	A = 0.6, B = 0.3, C= 0.3, D= 0.3, ABCD= 1.6							

A= Variety, B= Treatment, C= Time, D= Seed lot

ppm and 92.5 by 20 ppm) in fresh (Freshly harvested and 5-6 month old) seeds as compared to control (79.5) and naturally aged seeds which showed (83.5 by 10 ppm and 85.0 by 20 ppm) percent germination. Hence, maximum improvement in percent germination was achieved in seeds treated with GA_3 at 20 ppm for 48 h at 25°C as compared to 24 h in both aged (88.5) and fresh seeds (95.0).

The higher seed quality parameters in seeds treated with 20 ppm GA_3 was attributed to enlarged embryos, higher rate of metabolic activity and respiration, better utilization and mobilization of metabolites to growing points and higher activity of enzymes. The effect of such invigoration treatments on tomato seeds were in accordance with the observations made by Pandita *et al.* (2003) who suggested that seed treatments increased the germination of ageing seeds of tomato. Tzortzakis (2009) stated that treatment with KNO_3 and GA_3 may improve rapid and uniform seedling emergence and plant development in nurseries or in green houses. Many seed priming treatments have been used to reduce the damage of ageing and invigorate their performance in different crops (Basra *et al.* 2003; Farooq *et al.* 2009).

Vigour Index I:

The studies on the effect of seed priming with water, KNO_3 and GA_3 solution for 24 h and 48 h revealed that, the priming treatments significantly influenced the vigour index I of both fresh and naturally aged seeds of both the tomato varieties Varkha Bahar-1 and Varkha Bahar-2. Fresh seeds hydrated for 48 h showed an increase in percent germination and seedling length and hence increased vigour index I in comparison to control as well as naturally aged seeds hydrated for 48 h at 25 °C in Varkha Bahar-1.

Aged seeds hydrated for 24 h showed less vigour index I as compared to the fresh seeds. Variety Varkha Bahar-1 showed more vigour index as compared to Varkha Bahar-2. The fresh and naturally aged seeds treated with KNO_3 at the concentration of 150 mM exhibited increased vigour index I in 48 h seed treatment in comparison to control along with 24 h seed treatment at 25°C in Varkha Bahar-1. Seeds treated for 24h with KNO_3 at 150 mM concentraton caused more increase in vigour index I as compared to the 50 mM seed treatment for 24 h in both fresh as well as aged seeds. The fresh seeds exhibited much increase in vigour index I than naturally aged seeds in both the tomato varieties but more increase was observed in variety Varkha Bahar-1.

Table 2. Effect of seed treatments on vigour index I of seedlings of fresh and aged seeds in tomato (*Lycopersicon esculentum* L.)

Treatments	Varkha Bahar-1				Varkha Bahar-2			
	24 h		48 h		24 h		48 h	
	Fresh	Aged	Fresh	Aged	Fresh	Aged	Fresh	Aged
Control	1272.0	1045.3	1272.0	1045.3	1147.6	902.4	1147.6	902.4
Hydration	1425.6	1147.5	1546.6	1232.4	1279.5	1000.8	1409.4	1110.0
KNO_3(50mM)	1610.2	1405.1	1781.9	1532.2	1490.4	1244.1	1628.2	1390.4
KNO_3(150mM)	1795.5	1581.2	1960.1	1718.1	1677.1	1446.7	1771.9	1567.2
GA_3 (10ppm)	1951.1	1745.1	2148.3	1881.0	1827.3	1621.8	1940.4	1703.5
GA_3 (20ppm)	2109.0	1819.0	2299.0	2035.5	1951.1	1736.8	2113.6	1853.0
CD at 5%	A = 0.6 , B= 0.3, C= 0.3, D= 0.3, ABCD= 1.7							

A= Variety, B= Treatment, C= Time, D= Seed lot

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The higher increase was observed in vigour index I of fresh seeds of Varkha Bahar-1 being treated with GA_3 at 20 ppm for 48 h over the seeds treated with GA_3 (10 ppm) for 48 h in comparison with Varkha Bahar-2. Similar effect was observed in the naturally aged seeds of Varkha Bahar-1 treated with GA_3 at both the concentrations (10 ppm and 20 ppm) for 48 h at 25 °C.

Likewise, the fresh seeds treated for 24 h at 25 °C with GA_3 (10 and 20 ppm) showed increased vigour index I as compared to naturally aged seeds. The seedling vigour index I was maximum in seeds treated with GA_3 at the concentration of 20 ppm for 48 h. Jagadish *et al* (1994) also reported the improvement in germination and seedling vigour index of seeds treated with GA_3 over untreated control in tomato, capsicum and onion.

Vigour Index II

The results on seedling vigour index II as influenced by different seed treatments are presented in Table (3), which showed an increase in vigour index II by all the treatments in comparison with control. The hydration treatment of fresh seeds for 48 h recorded higher vigour index II as compared to the seed treatment for 24 h along with the control. Lower vigour index was observed in the naturally aged seeds being hydrated for 24 h at 25 °C as compared to the seed treatment for 48 h. The naturally aged seeds showed less vigour index II due to less percent germination and dry weight as compared to the fresh seeds in both the varieties Varkha Bahar-1 and Varkha Bahar-2 but the maximum vigour index II was recorded in tomato variety Varkha Bahar-1.

The KNO_3 seed treatment of fresh seeds at the concentration of 150 mM for 48 h recorded higher vigour index II as compared to control along with naturally aged seeds being given the same treatment for 48 h duration. Lower vigour index was observed in the fresh as well as naturally aged seeds treated for 24 h as compared to 48 h. The fresh seeds treated with the higher concentration (150 mM) for 48h showed higher vigour index II as compared to the aged seeds as well as 24 h seed treatment. Due to maximum dry weight and percent germination recorded with GA_3 at 20 ppm concentration for 48 h in the fresh seeds as compared to 24 h and 10 ppm seed treatment. Maximum vigour index II was observed in varkha bahar I as compared to Varkha Bahar-2.

Vigour enhancement by the incorporation of growth regulators in priming solutions were might be due to increased cell division within the apical meristem of seedling root, which caused an increase in plant growth. Moreover, hormonal treatments maintain the IAA and cytokinin levels in the plant tissues, which enhance the cell division (Sakhabutdinova *et al.* 2003). Treated tomato seeds also had increased synthesis of DNA (Bino *et al.* 1992).

Electrical conductivity

Highest EC of seed leachates was recorded in untreated seeds. All the seed treatments resulted in lower EC of seed leachates that might be the result of membrane repair during the hydration process as reported earlier by Basra *et al.* (2003) in fine rice. The hydration treatment of fresh seeds showed significant decrease in electrical conductivity in Varkha Bahar-1 at 48 h of treatment (0.338) as compared to 24 h (0.343) along with control (0.350). Likewise, the hydrated aged seeds of Varkha Bahar-1 for 48 h (0.354) also led to more decrease in electrical conductivity on comparison with 24 h (0.362) and control (0.369). The decrease in electrical conductivity was also observed in the hydrated fresh as well as naturally aged seeds of Varkha Bahar-2 for 24 h (0.356 for fresh and 0.372 for aged) and 48 h (0.350 for fresh and 0.364 for aged) as compared to control (0.361 fresh and 0.380 aged).

The lower electrical conductivity was notified in the fresh (0.321) as well as naturally aged seeds (0.336) of Varkha Bahar-1 treated with KNO_3 at 150 mM for 48 h at 25°C as compared to the treatment of seeds with low concentration

Table 2. Effect of seed treatments on vigour index II of seedlings of fresh and aged seeds in tomato (Lycopersicon esculentum L.)

Treatments	Varkha Bahar-1				Varkha Bahar-2			
	24 h		48 h		24 h		48 h	
	Fresh	Aged	Fresh	Aged	Fresh	Aged	Fresh	Aged
Control	116.86	104.53	116.86	104.53	107.92	92.35	107.92	92.35
Hydration	123.12	110.92	142.95	128.70	113.83	99.36	120.69	104.30
KNO3 (50mM)	133.63	120.11	157.43	141.81	126.36	105.04	132.76	116.92
KNO3 (150mM)	157.32	140.99	179.00	159.36	141.45	123.56	146.38	133.16
GA3 (10ppm)	183.47	152.80	193.44	168.43	150.68	132.84	156.99	141.27
GA3 (20ppm)	192.40	165.75	204.25	180.54	163.78	145.29	171.10	152.15
CD at 5%	A = 0.9, B= 0.5, C = 0.5, D= 0.5, ABCD= 2.4							

A= Variety, B= Treatment, C= Time, D= Seed lot

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Table 3. Effect of seed treatments on electrical conductivity (μS cm^{-1} g^{-1}) in fresh and aged seeds in tomato (*Lycopersicon esculentum* L.)

Treatments	Varkha Bahar-1				Varkha Bahar-2			
	24 h		48 h		24 h		48 h	
	Fresh	Aged	Fresh	Aged	Fresh	Aged	Fresh	Aged
Control	0.350	0.369	0.350	0.369	0.361	0.380	0.361	0.380
Hydration	0.343	0.362	0.338	0.354	0.356	0.372	0.350	0.364
KNO_3(50mM)	0.331	0.356	0.327	0.347	0.344	0.366	0.339	0.334
KNO_3(150mM)	0.325	0.345	0.321	0.336	0.337	0.352	0.333	0.323
GA_3 (10ppm)	0.310	0.332	0.303	0.325	0.322	0.341	0.318	0.311
GA_3 (20ppm)	0.304	0.325	0.297	0.312	0.315	0.333	0.309	0.301
CD at 5%	A = 0.5942, B = 0.3431, C= 0.3431 , D= 0.3431 , ABCD = 1.6808							

A= Variety, B= Treatment, C= Time, D= Seed lot

of KNO_3 *i.e.* at 50 mM along with control. Hence, the treatment of seeds treated for 24 h with both the concentrations of KNO_3 (50 mM amd 150 mM) did not show much significant effect as compared to the seed treatment for 48 h.

Seed treatment with GA_3 at 20 ppm showed appreciably lesser electrical conductivity in fresh seeds (0.297) of variety Varkha Bahar-1 as compared to the control (0.350) and treated seeds and aged seeds (0.311) for 48 h. Similarly, the seed treatment with GA_3 at 10 ppm also showed the decrease in electrical conductivity in both fresh as well as naturally aged seeds being treated for time interval of 24 h and 48 h. Thus, seed priming treatments had significant effect on electrical conductivity of seeds and the lowest seedling electrical conductivity was obtained for fresh seeds for 48 h by GA_3 at 20ppm. The lower electrical conductivity of seed leachate for GA_3 treated seeds may be due to beneficial effect of growth regulator in strengthening the cell membrane integrity and permeability (Kurdikeri 1991). Hence, It is concluded that the vigour of aged seeds could be improved using GA_3 and KNO_3 in tomato and this improvement is attributed to the seed treatments which repair the age related cellular and sub cellular damage that may accumulate during seed development of low vigour seeds

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Effect of Drip Irrigation and Fertigation on Yield, Quality and Input Use Efficiency in Cucumber

Amar Jeet Gupta* and Salwee Yasmin

Division of Olericulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar-191 121, Srinagar (J&K)
**E-mail: guptaaj75@yahoo.co.in*

Abstract: Studies were conducted to investigate the effect of drip irrigation and fertigation on yield, quality, water and fertilizer use efficiency of cucumber hybrid SH-CH-1 during *Kharif* 2007-08. The experiment comprised of sixteen treatment combinations replicated four times. The treatments include 4 levels of irrigation *viz;* 100%, 80% & 60% ET trough drip and 100% surface irrigation; and 4 levels of fertilizers application *viz*; 100%, 80% and 60% recommended NPK through fertigation and 100% recommended NPK through manual. Surface irrigation and manual fertilizers application were treated as control. Observations were recorded for yield and quality characteristics. The results revealed that the treatment combination of 80% ET through drip + 80% recommended NPK through fertigation produced maximum yield (1444.1 q/ha) and was significantly superior over all other treatments in terms of quality of cucumber fruit except vitamin C content, which was recorded maximum (46.30 mg/100 g) with treatment combination of 100% ET through drip + 100% recommended NPK through fertigation. Water use efficiency was found significantly superior with 60% ET through drip over other treatments. The highest water use efficiency (106.3 q/ha cm) was noticed with the treatment combination of 60% ET through drip + 80% recommended NPK through fertigation. In terms of fertilize use efficiency, 60% recommended NPK through fertigation was found significantly superior over other treatments. The highest fertilizer use efficiency (NUE-32.5 q/kg N, PUE & KUE 75.9 q/kg P & K) was observed with the treatment combination of 80% ET through drip + 60% recommended NPK through fertigation. The highest benefit cost ratio (5.99:1) was noticed in best treatment combination i.e. 80% ET through drip + 80% recommended NPK through fertigation.

Key Words: Drip irrigation, water and fertilizer use efficiency, quality parameters and cucumber

Water management assumes paramount importance to reduce the wastage of water to increase the water use efficiency and ensure equitable distribution. Although India has the largest irrigation system in the world, its water use efficiency is not more 40% (Magar, 2007). If it continues, the water crisis would lead to reduced production and productivity, which would affect quality of life of people as well. So there is need to improve the irrigation for maximum water use efficiency and a shift in focus is now required to produce more with less water and minimum maladies. Drip irrigation has been recognized as an answer to meet the increasing demands of water for irrigation, especially for horticultural crops. It is a method of watering plants frequently with desired volume of water, thereby minimizing conventional losses, deep percolation, run-off, and soil water evaporation. A considerable saving in water and fertilizer, increased growth, yield and quality of vegetables under drip irrigation has been reported by Singh and Singh (1978); and Bahadur and Rai (2006). The productivity of any system is based on effective utilization of water and resources with other agricultural inputs. The use of fertilizers and chemicals with irrigation provides better use efficiency and quality of produce. Drip irrigation offers this advantage of fertilizer application. Several workers have reported success of drip irrigation and fertigation technology in cucumber in terms of increased yield and quality and better water use efficiency and fertilizer use efficiency (Kaniszewski and Elkner, 2002; Feler, 2006; and Suojala *et al.,* 2006). However, limited information is available regarding the effect of drip irrigation in conjunction with fertigation on yield, quality, water use efficiency and fertilizer use efficiency in cucumber (*Cucumis sativus*). Therefore, investigation was taken up to study the response of cucumber hybrid SH-CH-1 under drip irrigation and fertigation system in Kashmir valley.

MATERIAL AND METHODS

The experiment was conducted during *Kharif* season of 2007-08 at the experimental farm of Division of Olericulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar (J&K). The experiment was laid out in factorial randomized block design with sixteen treatment combinations and four replications. The treatments included 4 levels of irrigations *viz;* 100%, 80% & 60% evapotrams priration (ET) through drip and 100% surface irrigation, and 4 levels of fertilizers application *viz;* 100%, 80% & 60% recommended NPK through fertigation and 100% recommended NPK through manual application. Surface irrigation and manual fertilizer

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application were treated as control. The volume of water for 100 per cent ET based on pan evaporation was computed using following equation:

$$V = [DE \times CF \times AA \times PC] / IE$$

Where, V= Volume of water required (liter/plant/day), DE = Daily pan evaporation (mm), CF = Crop factor, AA = Area allotted per plant (m^2), PC = Pan coefficient and IE = Irrigation efficiency as a decimal.

The data on average pan evaporation (Ep) and monthly effective rainfall (Re) during the cropping period are given in Table 1. The pan factor value was 0.75 as suggested for USDA class A pan. The area allotted per plant was 0.48 m^2. Hybrid cucumber (SH-CH-1) was sown in the field on 16th May 2007 with 2 rows per plot accumulating total 18 plants/plot keeping row to row and plant to plant distance 120 and 40 cm, respectively. The drip system was laid out parallel to the crop rows and each lateral with emitter distance at 40 cm and 2.2 lph discharge rate served one row of cucumber. The amount of water actually applied by irrigation system was based on climatologically approach (Table 1). Irrigation was scheduled on alternate days in case of drip irrigation, whereas the surface irrigation was given according to the locally adopted frequently. Fertigation with RFD 70:30:30 kg NPK/ha was given according to the treatments in 10 split doses at 10 days after sowing. However in case of manually fertilized plots, half dose of nitrogen (Urea) and full doses of phosphorus (SSP) and potassium (MOP) were applied as basal doses while the remaining half dose of nitrogen was applied 30 and 45 days after sowing as top dressing. All other packages and practices were adopted as recommended for the region.

Cucumber fruits were harvested in various pickings and data were added to estimate the total fruit yield. Standard procedures were followed for estimation of average fruit weight, number of fruits/plot, total soluble solids, vitamin C content and chlorophyll content of cucumber. Volumetric method was used for calculating the uniformity coefficients of drip irrigation system (Raina *et al.*, 1999). The water use efficiency was computed dividing total yield (q/ha) with total water applied (cm) including effective rainfall. Similar formula was adopted for calculating fertilizer use efficiency, where total yield (q/ha) was divided by amount of fertilizer applied (kg/ha). Fertilizer use efficiency was calculated separately for N, P and K.

The performance of drip system was studied before conducting the experiment. The drip system performed at a very high uniformity of water application. The uniformity coefficient was found to 92.7% indicating the excellent performance of drip irrigation system in supplying water uniformly throughout the lateral lines. The effects of various treatments on yield and quality were recorded and analyzed stastically. Water use efficiency and fertilizer use efficiency was also determined.

RESULTS AND DISCUSSION

Yield and yield components

Results confirmed superiority of drip irrigation and fertigation system over conventional method of irrigation and fertilizer application in terms of increased fruit yield, better quality, and enhanced water and fertilizer use efficiency of cucumber hybrid SH-CH-1. All the irrigation levels increased yield significantly as compared to surface method of irrigation. The maximum fruit length (28.31cm), fruit diameter (4.66 cm), number of fruits/plot (347.18), average fruit (443.80 g) and yield (1341.2 q/ha) was recorded when irrigation was given at 80% ET through drip which was found to be 31% higher in comparison with surface irrigation (Table 2). The increased yield under drip irrigation might be due to the availability of moisture content in the root zone of the plant resulting easy intake of moisture and nutrients by the plant from the soil. A significant increased yield in cucumber under drip irrigation has also been reported by Kaniszewski and Elkner (2002) and Feler (2006).

The response of various fertigation levels in cucumber hybrid SH-CH-1 showed considerable effect on average fruit weight and yield of cucumber. Fertigation with 80% recommended NPK produced the maximum fruit length

Table 1. Pan evaporation, effective rainfall, crop factor and volume of water applied during experimentation period.

Month	Average pan evaporation (mm/day)	Effective rainfall (mm)	Crop factor	Volume of water applied (cm)
May	3.8	34.1	0.4 (after 16th May)	0.565
June	4.7	52.3	0.4 (up to 14th June)0.7 (from 15th June)	4.817
July	4.5	54.0	0.7 (up to 24th July)0.9 (from 25th July)	3.385
August	5.0	46.4	0.9 (up to 23rd Aug)0.8 (from 24th Aug)	5.937
September	3.7	9.6	0.8 (up to 17th Sept.)	2.708

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Table 2: Effect of drip irrigation on yield, quality and water use efficiency (WUE) in cucumber

Treatment	Yield (q/ha)	Fruit length (cm)	Fruit diameter (cm)	No. of fruits/ plot	Av. fruit weight (g)	Dry matter content	TSS (%)	Chlorophyll content (mg/100 g)	Vitamin C content (mg/100 g)	Water applied (cm)	WUE (q/ha-cm)
I_1	1262.0	27.59	4.51	317.75	366.32	3.75	2.63	0.69	41.8	21.7	58.1
I_2	1341.2	28.31	4.66	347.18	443.80	4.35	2.76	0.73	39.2	17.4	77.0
I_3	1278.9	28.01	4.57	332.86	406.78	4.09	2.73	0.69	35.9	13.0	98.3
I_4	1071.5	27.05	4.37	301.55	338.87	3.49	2.41	0.65	31.4	28.0	38.2
CD at 5%	-	1.12	0.17	4.27	24.95	0.37	0.20	0.009	2.59	-	-

I_1 = 100% ET through drip irrigation; I_2 = 80% ET through drip irrigation; I_3 = 60% ET through drip irrigation; I_4 = 100% Surface irrigation.

(28.24 cm), fruit diameter (4.67cm), number of fruits/plot (355.81), average fruit weight (421.33g) and yield (1361.5 q/ha), whereas the manual fertilizer application recorded minimum values for these traits (Table 3). The increased yield under fertigation may be due to the reason that fertilizer application through fertigation is restricted to the wetted volume of soil, where the active roots were concentrated and hence, was fully available to plants. Similar results were reported by Surve *et al.* (2002) and Kaniszewski and Elkner (2002).

Drip irrigation in conjunction with fertigation was found more effective in enhancing yield of cucumber. All treatment combinations of drip irrigation and fertigation recorded maximum yield over surface method of irrigation and manual fertilizer application. The treatment combination of 80% ET through drip + 80% recommended NPK through fertigation produced maximum fruit length (28.70 cm), fruit diameter (4.77 cm), number of fruits/plot (386.00), average fruit weight (477.16 g) and yield (1444.1q/ha) (Table 4). Our findings are in accordance with the earlier findings of Surve *et al.* (2002); Kaniszewski and Elkner (2002); and Feler (2006).

Quality characteristics

The favourable factors evolved due to the adoption of drip irrigation resulted in multiple benefits including quality improvement. In case of quality characteristics of cucumber, drip irrigation was also found superior than the conventional method (Table 2). Among various irrigation levels, 80% ET through drip noticed maximum values for fruit dry matter content (4.35%), total soluble solids (2.76%) and fruit chlorophyll content (0.73 mg/100 g). However, vitamin C content noticed a decreasing trend with decreasing irrigation levels. The maximum vitamin C content (41.8 mg/100 g) was recorded with 100% ET through drip.

Fertigation levels also exhibited significant effect on quality characteristics of cucumber (Table 3). The maximum fruit dry matter content (4.36%), total soluble solids (2.77%) and chlorophyll content (0.73 mg/100 g) were recorded with 80% recommended NPK through fertigation. However, total soluble solids and chlorophyll content were statically at par with 60% recommended NPK through fertigation. Vitamin C content was found maximum (40.9 mg/100g) with 100% recommended NPK through fertigation. Similar results of quality improvement were also reported by Kaniszewski and Elkner (2002) and Gupta *et al.* (2010).

Table 3: Effect of fertigation on yield, quality and fertilizer use efficiency (FUE) in cucumber

Treatment	Yield (q/ha)	Fruit length (cm)	Fruit diameter (cm)	No. of fruits/ plot	Av. fruit weight (g)	Dry matter content (%)	TSS (%)	Chlorophyll content (mg/ 100 g)	Vitamin C content (mg/ 100 g)	NUE (q/kg N)	PUE (q/kg P)	KUE (q/kg K)
F_1	1204.2	27.69	4.50	312.65	389.97	3.75	2.51	0.68	40.9	17.2	40.1	40.1
F_2	1361.5	28.24	4.67	355.81	421.33	4.36	2.77	0.73	38.5	24.3	56.7	56.7
F_3	1277.6	27.96	4.56	332.67	396.49	4.04	2.72	0.71	36.1	30.1	70.9	70.9
F_4	1110.3	27.07	4.40	298.21	347.98	3.53	2.53	0.65	32.8	15.8	37.0	37.0
CD at 5%	-	1.12	0.17	4.27	24.95	0.37	0.20	0.009	2.59	-	-	-

F_1 = 100% RFD through fertigation; F_2 = 80% RFD through fertigation; F_3 = 60% RFD through fertigation; F_4 = 100% RFD through manual application.

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Table 4. *Interaction effect of drip irrigation and fertigation on yield, quality, WUE and FUE in cucumber*

Treatment combinations	Yield (q/ha)	Fruit length (cm)	Fruit diameter (cm)	No. of fruits/ plot	Av. fruit weight (g)	Fruit dry matter content (%)	TSS (%)	Chlorophyll content (mg/100 g)	Vitamin C content (mg/100 g)	Water applied (cm)	WUE (q/ha- cm)	NUE (q/kg N)	PUE (q/kg P)	KUE (q/kg K)
I_1F_1	1207.90	27.45	4.47	307.25	355.13	3.51	2.52	0.68	46.30	21.7	55.6	17.2	40.2	40.2
I_1F_2	1372.80	28.10	4.67	352.25	396.45	4.19	2.80	0.73	42.35	21.7	63.2	24.5	57.2	57.2
I_1F_3	1309.20	27.70	4.52	311.75	382.64	3.85	2.78	0.73	41.45	21.7	60.3	31.1	72.7	72.7
I_1F_4	1158.10	27.12	4.37	299.75	331.07	3.43	2.43	0.64	37.10	21.7	53.3	16.5	38.6	38.6
I_2F_1	1319.30	28.20	4.62	331.25	430.29	4.15	2.63	0.72	42.30	17.4	75.8	18.8	43.9	43.9
I_2F_2	1444.10	28.70	4.77	386.00	477.16	4.73	2.87	0.77	40.85	17.4	82.9	25.7	60.1	60.1
I_2F_3	1367.50	28.45	4.70	355.25	450.71	4.58	2.83	0.75	38.65	17.4	78.5	32.5	75.9	75.9
I_2F_4	1234.20	27.92	4.57	316.25	417.07	3.95	2.73	0.71	35.20	17.4	70.9	17.6	41.1	41.1
I_3F_1	1216.40	27.95	4.55	329.60	387.15	3.98	2.55	0.69	38.65	13.0	93.5	17.3	40.5	40.5
I_3F_2	1382.10	28.29	4.68	353.00	442.32	4.39	2.84	0.73	37.70	13.0	106.3	24.6	57.5	57.5
I_3F_3	1327.30	28.15	4.62	343.10	419.22	4.35	2.82	0.70	34.65	13.0	102.1	31.6	73.7	73.7
I_3F_4	1190.10	27.65	4.45	305.75	378.43	3.63	2.73	0.67	32.80	13.0	91.5	17.0	39.6	39.6
I_4F_1	1073.40	27.17	4.35	282.50	387.32	3.36	2.37	0.65	36.50	28.0	38.3	15.3	35.7	35.7
I_4F_2	1247.20	27.90	4.55	332.00	369.39	4.11	2.60	0.72	33.15	28.0	44.5	22.2	51.9	51.9
I_4F_3	1106.70	27.55	4.40	320.60	333.41	3.39	2.45	0.66	29.80	28.0	39.5	26.3	61.4	61.4
I_4F_4	859.00	25.60	4.20	271.10	265.38	3.11	2.25	0.60	26.15	28.0	30.6	12.2	28.6	28.6
CD at 5%	-	2.25	0.34	8.54	49.90	0.74	0.40	0.02	5.19	-	-	-	-	-

I_1 = 100% ET through drip irrigation; I_2 = 80% ET through drip irrigation; I_3 = 60% ET through drip irrigation; I_4 = 100% Surface irrigation.

F_1 = 100% RFD through fertigation; F_2 = 80% RFD through fertigation; F_3 = 60% RFD through fertigation; F_4 = 100% RFD through manual application

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More improvement in quality characteristics of cucumber was observed with the combined effect of drip irrigation and fertigation (Table 4). The quality characteristics were found significantly superior with the combined effect of drip irrigation and fertigation than their corresponding values of drip irrigation and fertigation alone. However, among various treatment combinations, 80% ET through drip + 80% recommended through fertigation gave maximum fruit dry matter content (4.73%), total soluble solids (2.87%) and chlorophyll content (0.77 mg/100g) whereas the application of 100% ET through drip + 100% recommended NPK through fertigation registered maximum vitamin C content (46.30 mg/100g). The improved quality characters of cucumber might be attributed due to the fact that drip irrigation and fertigation allows better water and nutrient management which helps plants to complete all metabolic process at appropriate time. This also helps in keeping enzyme systems active, thus leading to better quality fruits. The highest benefit cost ratio (5.99:1) was noticed in best treatment combination i.e. 80% ET through drip + 80% recommended NPK through fertigation. Our findings are in general agreement with the earlier findings of Kaniszenski and Elkner (2002), Samra (2005), Alcantar *et al.* (1999) and Gupta *et al.* (2010).

Water and fertilizer use efficiency (WUE & FUE)

Higher water and fertilizer use efficiency were observed under drip irrigation and fertigation by decreasing their consumptive use, leading to better efficiency in comparison with normal practices of irrigation and fertilizer application. Results revealed that considerably higher water use efficiency obtained by drip irrigation levels. The higher water use efficiency (98.3 q/ha cm) was recorded with 60% ET through drip whereas lowest water use efficiency (38.2 q/ha cm) was observed with surface irrigation (Table 2). The reason for lower water use efficiency might be due to restriction of nutrient uptake caused by excessive moisture in the soil. The results confirm with earlier findings of Raina *et al.* (1999), Srinivas *et al.* (1989) and Feler (2006).

Parikh *et al.* (1996) reported that in vegetable crops, fertigation leads not only in saving fertilizer application but also enhances yield and quality of produce and minimizes leaching losses. Fertigation with 60% recommended NPK produced the maximum fertilizer use efficiency (NUE-30.1 q/kg N, PUE-70.9 q/kg P and KUE-70.9 q/kg K) whereas the manual fertilizer application showed least fertilizer use efficiency (Table 3). Similar results have earlier been reported by Haltlge *et al.* (2002), Surve *et al.* (2002), Choudhary *et al.* (2002), Suojala *et al.* (2006) and Gupta *et al.* (2010).

In case of interaction effect of drip irrigation and fertigation, maximum water use efficiency (106.3 q/ha-cm) was observed with 60% ET through drip + 80% recommended NPK through fertigation (Table 4). The treatment combination of 80% ET through drip + 60% NPK through fertigation registered maximum fertilizer use efficiency (NUE-32.5 q/kg N; and PUE & KUE-75.9 q/kg P & K. These findings confirm the earlier findings of several workers like Haltlge *et al.* (2002), Surve *et. al.* (2002), Gupta *et al.* (2008) and Gupta *et al.* (2010).

It can be concluded that proper management of drip irrigation and fertigation with appropriate amount of water and fertilizers significantly enhance the yield and quality of cucumber with maximum water and fertilizer use efficiency.

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Performance of Diversified Cropping Systems under Organic, Integrated and Chemical Farming in Punjab

C.S. Aulakh*, M.S. Gill, S.S. Walia, R.K. Mahey and U.S. Walia

Department of Agronomy, Punjab Agricultural University, Ludhiana-141004, Punjab, India
**E-mail: csaulakh@rediffmail.com*

Abstract: A field experiment was conducted at Punjab Agricultural University, Ludhiana during 2004-07 to compare organic, integrated and chemical farming systems in basmati rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L. emend Fiori & Paol.)-green manure, turmeric (*Curcuma longa* L.)-onion (*Allium cepa* L.), summer groundnut (*Arachis hypogea* L.)-garlic (*Allium sativum* L.), maize (*Zea mays* L.)-wheat (*Triticum durum*)-cowpea fodder (*Vigna unguiculata* (L.) Walp) and rice (*Oryza sativa* L.)-garlic+mentha (*Mentha arvensis* L.) cropping systems. The economic yields of basmati rice, rice, maize, groundnut, wheat and onion were statistically at par under organic, integrated and chemical farming whereas turmeric, garlic, mentha and cowpea yields were significantly higher under organic farming when 20% price premium on organic produce was considered. Productivity in terms of rice equivalent yield (REY) was highest under organic farming followed by integrated and chemical farming. turmeric and garlic+mentha gave highest REY in *kharif* and *rabi* season, respectively. The system REY was highest in rice-garlic+mentha followed by turmeric-onion. Total system productivity was 36.8 and 18.7% higher under organic farming than chemical and integrated farming, respectively. Total system productivity (37.9 t ha^{-1}), per day productivity (98.5 kg ha^{-1} day^{-1}) and land use efficiency (98.6%) were highest in rice-garlic+mentha cropping system.

Key words: Chemical, cropping system, farming, integrated, nutrition, organic, productivity

The realistic approach in mainstream agriculture is to have an integrated approach to conserve the precious natural resources coupled with ensured food security for the burgeoning population of 1210 million. Integrated plant nutrient-supply system is emerging as the most logical concept for managing long term soil fertility and productivity (Yadav and Kumar, 2009). The integration of organic and inorganic sources may help in minimizing the cost of chemical fertilizers, improve crop performance and soil fertility (Swarup, 1998). However, to take advantage of the emerging global organic food market, organic farming can be adopted in specific areas and crops. The global area under organic management has increased to 37.2 m ha with 54.9 billion USD sales of organic products (Yadav, 2011). Organic farming has been found to be more productive and energy efficient than conventional farming (Pimental *et al.*, 2005; Gundogmus and Bayramoglu, 2006) and performed significantly better in 18 environmental impact factors (Stolze *et al.*, 2000). Organic systems have less long-term yield variability (Peters, 1994; Smolik *et al.*, 1995). A survey of 208 projects in developing tropical countries, in which contemporary organic practices were introduced, showed average yield increase of 5-10% in irrigated crops and 50-100% in rainfed crops (Pretty and Hine, 2001). Organic farming relies on green manures, crop rotations, organic manures and composts and apart from sustained agricultural production it improves the soil health. The experiment was conducted to see the performance of different crops in cropping system mode under organic, chemical and integrated farming systems. The selection of cropping systems was such that it included either a green manure crop or a legume or a crop which is more responsive to organic manures. Turmeric, onion, garlic and maize are highly responsive to application of farmyard manure (PAU, 2012; PAU, 2012a).

MATERIAL AND METHODS

The field study was conducted at Punjab Agricultural University, Ludhiana during 2004 - 2007 to study the impact of organic, integrated and chemical farming practices on productivity of different crops in different cropping systems. The experimental site has sub-tropical and semi-arid type of climate and is situated at a height of 247 m above the mean sea level at 30°-54´ N latitude and 75°-48´ E longitudes. The soil of experiment site was loamy sand having pH 7.38 and had medium organic (wet digestion method) carbon (0.30%) content and 286.7, 37.1 and 151.2 kg ha^{-1} available (alkaline permanganate oxidisable) nitrogen, phosphorus (0.5 M $NaHCO_3$ extractable) and potassium (1 M ammonium acetate exchangeable), respectively. The experiment was laid out in split plot design with three management practices (organic, chemical and integrated) in the main plots and five cropping systems viz. basmati rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.)-green manure [CS-I], turmeric (*Curcuma longa* L.)-onion (*Allium cepa*) [CS-II], groundnut (*Arachis hypogea*)-garlic [CS-III], maize (*Zea mays*)-durum wheat-cowpeas (fodder) [CS-IV] and rice (*Oryza sativa* L.)-garlic+mentha (*Mentha*

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arvensis L.) [CS-IV] in sub plots. The agronomic practices followed and the nutrition supplied to the component crops were as per the recommendations of Punjab Agricultural University (Table 1). Basmati rice was grown after green manuring only without any organic manure or fertilizer in all the management systems. The experiment was conducted under assured irrigation facilities and irrigations to crops were given as per the recommended practices. The total annual rainfall during the cropping cycle was 426, 654, 695 and 529 during 2004, 2005, 2006 and 2007, respectively. The economic yields of all the crops were converted into rice equivalent yields to compare the productivity of different crop sequences (Yadav and Newaj, 1990). The system productivity values in terms of kg $ha^{-1}day^{-1}$ were worked out by dividing the total production in a crop sequence with the total duration of the crops in that particular sequence. The land use efficiency was calculated by taking total duration of each crop sequence divided by 365 days and expressed as percentage (Singh and Verma, 1998). The quantities of organic sources of nutrition under organic and integrated systems were calculated on the basis of nitrogen requirement of individual crops (Table 1) as nitrogen is a thrust element in organic farming (Magar, 2004). The quantity of these sources depended upon the percent nitrogen content in the respective source on dry weight basis. The organic sources used were farmyard manure (FYM), vermicompost and castor cake. The nitrogen content varied from 0.6-1.0, 0.95-1.5 and 2.15-2.5% in FYM, vermicompost and castor cake, respectively during different years of experimentation. The green manuring was done by sunnhemp (*Crotalaria juncea* L.) and its dry biomass production varied from 3.2-5.0 t ha^{-1} in different years. The green manure crop was incorporated into the soil one day prior to transplanting of rice. In integrated system, 50% of recommended nutrient requirement (on nitrogen basis) was made through organic sources and the rest 50% through chemical fertilizers (Urea, DAP and MOP). In chemical system, the entire nutrient requirements were met through chemical fertilizers. The entire quantity of organic sources was applied at the time of sowing. However, in case of chemical fertilizers, whole P and K were applied at sowing and N was applied in split doses as per the recommendations of Punjab Agricultural University, Ludhiana. The cowpea sown for fodder was raised on residual soil fertility and harvested after 50 days of sowing. The garlic + mentha intercrops were raised by growing garlic on 67.5 cm beds (37.5 cm bed surface and 30 cm furrow) and two rows of mentha on lateral sides of each furrow.

The insect pest management in chemical and integrated system was done by using the recommended insecticides where as the in organic system these were managed by using the biological agents, botanicals and biopesticides. In rice and basmati rice, *Trichogramma chilonis* and *T. japonicum* were released 7 times each @ 100000 ha^{-1} at weekly interval starting from 30 days after transplanting. In maize, *T. chilonis* @ 100000 ha^{-1} was released against maize stem borer at 10-15 days after sowing. The aphid attack in wheat was managed by using neem based pesticides.

Rice equivalent yields (REY) were calculated by taking into account the sale price of different component crops and their respective economic yields as per the formula:

$$\text{Rice equivalent yield (t ha}^{-1}) = \frac{\text{Economic yield (t ha}^{-1}) \times \text{Sale price (Rs)}}{\text{Sale price of rice (Rs)}}$$

The prices of inputs and sale price of products for the *kharif* 2011 and *rabi* 2011-12 were considered for economic analysis. The organic products were given 20% price premium except the cowpea fodder. The data on rice equivalent yield of different cropping systems were statistically analyzed by taking years as the replications by using statistical methods described by Gomez and Gomez (1984) and the software used was CPCS1 developed by the Department of Statistics, Punjab Agricultural University, Ludhiana.

RESULTS AND DISCUSSION

Productivity of crops

In *kharif* season, basmati rice, rice, maize and groundnut economic yields did not differ significantly with different management systems (Table 2). Turmeric rhizome and cowpea green fodder yields were significantly higher under organic and integrated management than chemical farming. However, organic and integrated farming in these two crops were statistically at par with each other. The warm and moist conditions in *kharif* season might have helped in sustained release of nutrients from organic sources. In *rabi* season, wheat and onion yields remained statistically similar under organic, integrated and chemical farming. Garlic yield in summer groundnut-garlic system and mentha yields in garlic+mentha system were significantly higher under organic and integrated farming than chemical farming but the former two management systems were statistically at par with each other. The higher turmeric and garlic yields under organic management might be due to reason that these are more responsive to organic manures (PAU, 2012; PAU, 2012a). Garlic yield in rice-garlic+mentha system gave significantly higher economic yields under organic farming than chemical farming but was statistically at par with

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Table 1. Agronomic practices followed for raising of various crops during the conduct of experiment

Crop	Variety	Sowing time	Transplanting	Seed rate (kg ha^{-1})	Spacing (cm)	Nutrients applied* (N, P_2O_5, K_2O kg ha^{-1})
Kharif season						
Sunnhemp	Local	1st week June	-	50	20 cm	-
Basmati Rice	Supper basmati	3rd week June	3rd week July	20	33 hills m^{-2}	-
Turmeric	Local	1st week May	-	2000	30 x 20	150, 25, 25
Groundnut	SG 99	1st week May	-	100	30 x 15	15, 20, 25
Maize	Paras	3rd week June	-	20	60 x 22	125, 60, 30
Rice	PR116	4th week May	4th week June	20	33 hills m^{-2}	125, 30, 30
Rabi season						
Wheat	PBW343	1st week November	-	100	20	125, 62.5, 30
Onion	Punjab Naroa	End October	End December	10	15 x7.5	100, 50, 50
Garlic	Punjab Garlic 1	2nd week October	-	625	15 x7.5	125, 62.5
Durum wheat	PDW274	4th week October	-	100	20	125, 62.5, 30
Cowpea	Cowpea 88	2nd week April	-	50	30 cm	-
Garlic+mentha	Punjab Garlic 1	2nd week October	-	625	7.5 x7.5	125, 62.5
	MAS 1	-	3rd week January			

* nutrients applied to chemical management; organic manures were used to supply the N requirement only.

Table 2. Economic yield of crops under different management practices

Management System	Economic yield (t ha^{-1})											
	CS-I		CS-II		CS-III		CS-IV			CS-V		
	B. rice	Wheat	Turmeric	Onion	G. nut	Garlic	Maize	Wheat	Cowpea	Rice	Garlic	Mentha
Organic	2.95	4.42	25.7	9.78	2.18	9.20	4.88	4.70	30.5	5.79	7.43	0.099
Chemical	3.14	4.33	12.5	8.74	2.14	7.62	4.22	4.67	24.4	6.01	5.54	0.073
Integrated	3.37	4.59	24.4	11.3	2.23	9.28	4.81	4.87	28.7	6.59	6.77	0.115
CD (P=0.05)	NS	NS	5.8	NS	NS	0.87	NS	NS	3.2	NS	1.25	0.023

integrated farming. The chemical and integrated farming were also statistically at par with each other. Kharub and Chander (2008) and Sherchan *et al*., (1999) reported similar rice and lower wheat productivity under organic and inorganic cultivation.

Rice equivalent yields

Rabi and *kharif* season productivity and total system productivity in terms of rice equivalent yield of crops were significantly higher under organic than under chemical and integrated management (Table 3). This might be due to price premium on organic products as most of the crops had similar economic yields under different management systems. The *kharif* season productivity under integrated management was significantly better than chemical management but *rabi* season and total productivity were statistically at par under chemical and integrated management. The per day productivity was significantly better under organic than chemical and integrated management, the latter two being statistically at par with each other.

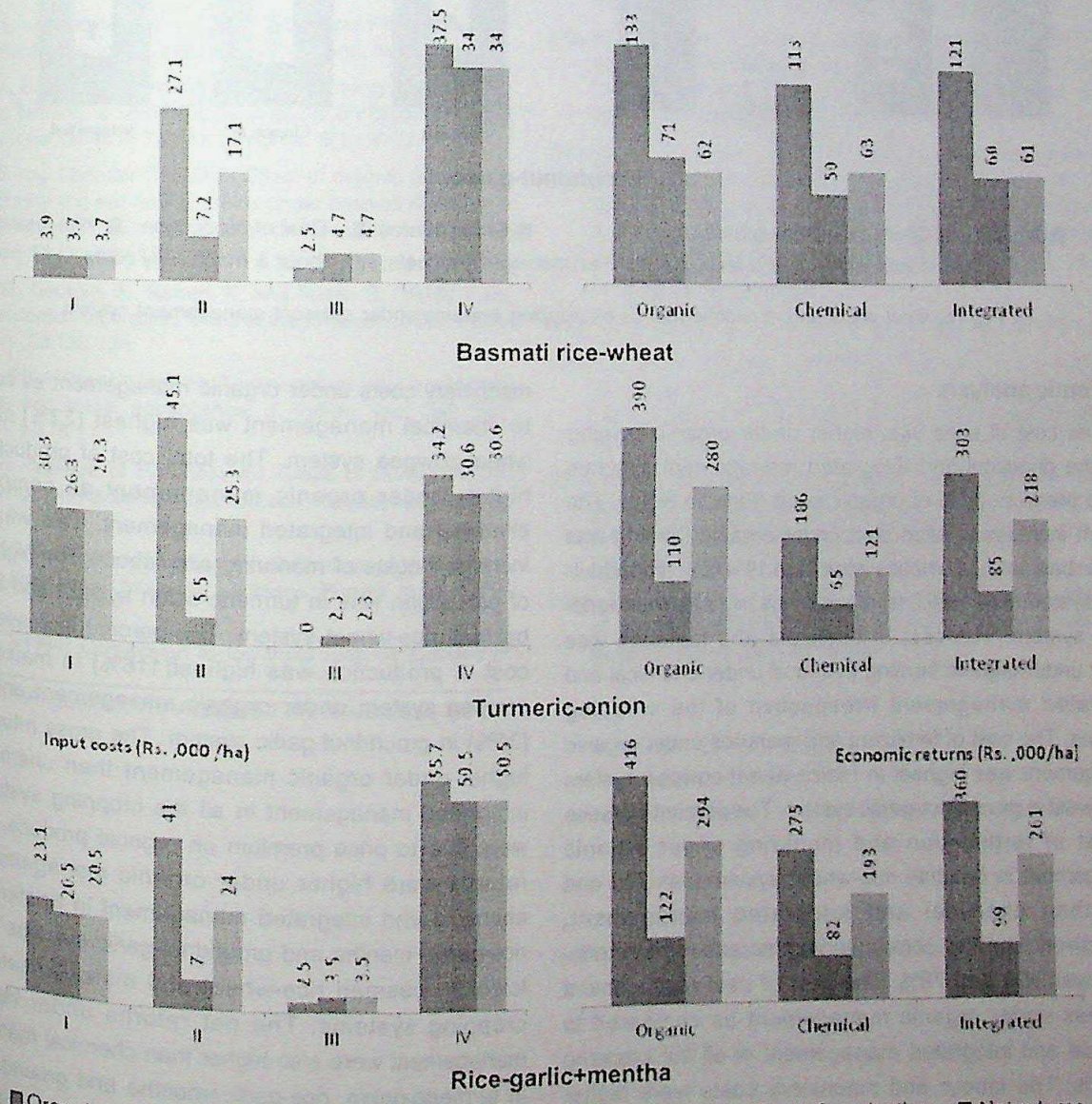
Among the cropping systems, significantly higher system productivity was obtained in CS-V than all the other cropping systems. The CS-II gave significantly higher productivity than CS-I, CS-III and CS-IV. CS-III was significantly better than CS-I and CS-II, the latter two being statistically at par with each other. The higher system productivity in CS-V was due to additional crop of mentha in the system. In CS-II, the increased productivity was due to higher economic yield of turmeric. In *kharif* season, significantly higher productivity was obtained in CS-II than all the other cropping systems. CS-I, CS-III and CS-V were statistically at par among one another. In *rabi* season, CS-V gave significantly higher productivity than all the other cropping systems. CS-III was significantly better than CS-I, CS-II and CS-V. The cropping systems, CS-I and CS-IV were statistically at par with each other. The per day productivity was significantly higher in CS-V than all the other cropping systems. CS-II was significantly better than CS-I and CS-IV but was statistically at par with CS-III. CS-IV gave significantly lowest per day productivity. Land use efficiency was highest in CS-V, followed by CS-II, IV, III and I.

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Table 3. Rice equivalent yields (REY), productivity and land use efficiency of different cropping and management systems

Management/Cropping System	REY (t ha^{-1})			Productivity (kg ha^{-1}day^{-1})	Land use efficiency (%)
	Kharif	*Rabi*	System		
Management system					
Chemical	6.5	12.5	19.0	61.9	-
Organic	10.9	15.2	26.0	78.9	-
Integrated	8.9	13.0	21.9	66.6	-
CD (P=0.05)	1.7	2.1	3.5	10.3	-
Cropping system					
Basmati rice-wheat (CS-I)	6.5	5.4	11.9	48.9	72.6
Turmeric-onion (CS-II)	21.3	7.2	28.5	85.3	95.9
Groundnut-garlic (CS-III)	5.2	18.1	23.3	77.9	82.2
Maize-*durum* wheat-cowpea (CS-IV)	4.4	5.8	10.2	34.9	90.4
Rice-garlic+mentha (CS-V)	6.5	31.4	37.9	98.5	98.6
CD (P=0.05)	1.8	1.8	4.1	12.6	-



I-Seed costs; II-Manures & fertilizers; III- Pest management costs; IV-Labour & machinery costs

Fig 1a. Input costs and economic returns of cropping systems under different management system

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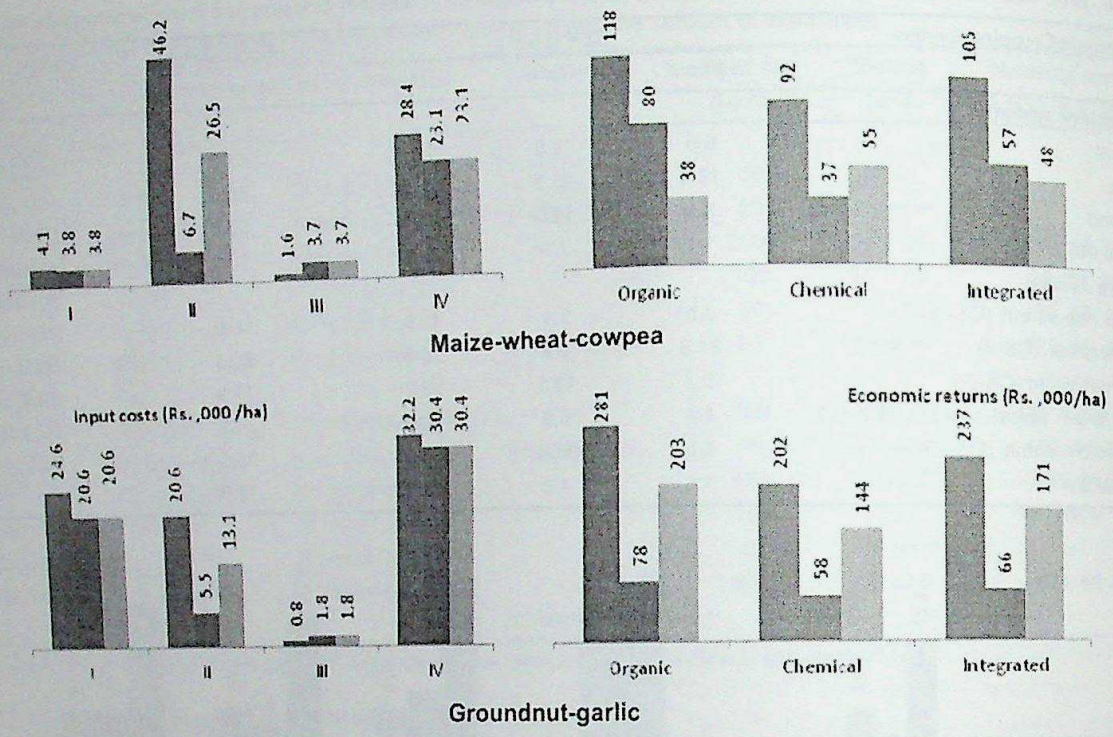


Fig 1b. Input costs and economic returns of cropping systems under different management system

Economic analysis

The cost of seed was higher under organic farming than the chemical and integrated management systems due to premium price of organic seed (Figs.1a & 1b). The percent increase in seed cost under organic farming was 5.4% in basmati rice-wheat system and 19.4 % in groundnut-garlic system. The total cost of seed was highest in turmeric-onion system. The cost of fertilizers and manures was higher under organic farming than that under chemical and integrated management irrespective of the cropping systems. The cost of fertilizers and manures under organic management was highest in maize-wheat-cowpea system and lowest in groundnut-garlic system. The percent increase in cost of fertilization and manuring under organic management in basmati rice-wheat system was 270 and 59% than chemical and integrated management, respectively and the corresponding increase in turmeric-onion was 720 and 78%. The cost of pest management was less under organic management as compared to chemical and integrated management in all the cropping systems. The labour and machinery costs were higher under organic management in all the cropping systems as the labour charges for weed management were included under this head. The percent increase in labour and machinery costs under organic management as compared to chemical management was highest (23%) in maize-wheat-cowpea system. The total cost of production was higher under organic management as compared to chemical and integrated management. This was due to increased costs of manuring and labour. The highest cost of production was in turmeric-onion system and lowest in basmati rice-wheat system. The percent increase in total cost of production was highest(116%) in maize-wheat-cowpea system under organic management and lowest (35%) in groundnut-garlic system. The gross returns were higher under organic management than chemical and integrated management in all the cropping systems and were due to price premium on organic produce. The net returns were higher under organic management than chemical and integrated management in turmeric-onion, rice-garlic+mentha and groundnut-garlic systems but were lower in basmati rice-wheat and maize-wheat-cowpea cropping systems. The net returns under integrated management were also higher than chemical management in turmeric-onion, rice-garlic+mentha and groundnut-garlic system. Davari and Sharma (2010) reported higher cost of cultivation with FYM and vermicompost under organic farming and Yadav *et al*., (2009) reported higher economic

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returns under organic farming. Lockeretz *et al.*, (1978) reported lesser market value of crops but comparable net income from the organic farms.

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Indian Journal of Ecology

Effect of Environment on Grain Yield, its Components and Quality Characters in Soybean [*Glycine max* L. Merill]

Minal Goyal*, B S Gill and Vikrant Tyagi

Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana – 141004, India
**E-mail: minalgoyal@rediffmail.com*

Abstract: Twenty one photo and thermo insensitive genotypes of soybean were exposed to wide range of environmental conditions (temperature and photoperiod) during different growth stages by sowing under three sowing dates viz. mid spring (spring), mid main (main) and mid late (late), to study the effect of environment on association between agronomic and quality characters. Analysis of variance for individual sowing dates and over dates of sowing revealed that genotype, environment and genotype x sowing date interaction were significant for the characters studied. Correlation analysis revealed that grain yield was significant positively correlated with plant height and number of pods per plant in all the three sowings except with plant height in late sowing. Oil content had highly negative significant correlation with protein content in spring sowing but showed no correlation in main and late sowings. Linolenic acid showed highly negative significant correlation with linoleic acid in spring sowing but showed highly positive significant correlation in main sowing and no correlation in late sowing. Oil content showed negative correlation with 100-seed weight in spring sowing, but showed positive correlation in late sowing and no correlation in main sowing. Linolenic acid showed significant negative correlation with oil content and oleic acid in all the three sowing dates.

Keywords: Soybean, phenotypic correlation coefficient, genotypic correlation coefficient and sowing dates.

Soybean is a short day plant and majority of its genotypes exhibit both photo and thermo sensitivity. Environmental factors such as day length and temperature affect production potential and quality characters in soybean. Normally soybean is sown in Punjab in first fortnight of main. There are significant yield losses when sowing is done beyond the recommended time of sowing. The performance of genotypes depends upon environment and there is interaction between genotypes and environments. When genotypes are grown under varying environmental conditions, they are expected to exhibit different magnitude of genetic variability for agronomic and quality characters. The ultimate goal in any breeding program is to identify and to study the interaction and its various components associated with yield and other traits. Correlation analysis establishes the extent and cause of association between yield and its attributes. Thus the present study was undertaken to determine the correlation between different grain yield and quality parameters using simple correlation coefficients under different sowing dates. This information may lead to the development of desirable selection indices for increasing grain yield and magnitude of quality characters.

MATERIAL AND METHODS

The experiment was conducted in the experimental area of Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana and quality parameters were estimated at oilseed quality lab (Department of Plant Breeding and Genetics). The experimental material consisted of twenty-one diverse photo and thermo insensitive genotypes of soybean which have been developed at Punjab Agricultural University, Ludhiana. These genotypes mature in 100-110 days under varying day length and temperature when sown over range of environments. These were sown in randomized complete block design with three replications of each under three sowing dates viz. spring (mid March), main season (second week of June) and late (second week of August). Weather conditions during different growing stages of crop in all the three sowing dates were entirely different. Each genotype was planted in three rows of three-meter length with row-to-row distance of 22.5 cm and plant-to-plant distance of 5.0 cm within rows in different sowings. Recommended agronomic practices were followed to raise the crop. The data was recorded on ten randomly taken plants with respect to days to flowering, plant height, number of pods per plant, grain yield, 100-seed weight, number of days to maturity, harvest index and quality characters. Crude protein was worked out by estimating nitrogen in the grain samples and multiplying it by 6.25. Oil content was determined by Nuclear Magnetic Resonance (NMR) and fatty acid profile was estimated through Gas Liquid Chromatography. Analysis of variance for single environment and over environments was carried out. The correlation coefficient between all the characters was calculated for individual environments.

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RESULTS AND DISCUSSION

Analysis of variance for individual dates of sowing revealed that mean squares for genotypes were significant for all the characters in all the three sowing dates. Analysis of variance over environments viz. dates of sowing showed that mean squares were significant for sowing dates, genotypes; genotype x sowing date interaction for all the characters studied indicating significant differences among genotypes, sowing dates and differential response of genotypes to different sowing dates.

Spring Sowing: In spring sowing first sowing plant height had positive and highly significant phenotypic correlation with days to flowering (0.50) (Table 1). Number of pods per plant had highly positive and significant correlation with days to flowering (0.36) and plant height (0.56). Grain yield per plant gave high positive correlation with number of pods per plant (0.69), plant height (0.34) and positive but significant only at 5% with days to flowering (0.29). Protein content gave positive correlation with grain yield per plant (0.27). There are four important fatty acids in soybean oil i.e. palmitic acid ($C_{16:0}$), oleic acid ($C_{18:1}$), linoleic acid ($C_{18:2}$) and linolenic acid ($C_{18:3}$). Stearic acid showed positive correlation with palmitic acid (0.32) and harvest index (0.27). Oleic acid recorded positive correlation with days to flowering (0.32). Linoleic acid also gave positive correlation with number of pods per plant (0.25), number of days to maturity (0.30) and 100-seed weight (0.25). Linolenic acid being unstable gives poor flavor and undesirable odour particularly in the oil that is heated during use. Linolenic acid gave high significant correlation with protein content (0.37). Highly negative correlation was shown by oil content with protein content (-0.35), palmitic acid with number of pods per plant (-0.37), linoleic acid with stearic (-0.45) and oleic acid (-0.84) and linolenic acid with linoleic acid (-0.46) and oil content (-0.37).

Main sowing: In case of main sowing grain yield per plant showed high and positive correlation with number of pods per plant (0.42) and plant height (0.37) (Table 2). Other characters, which have high positive correlations, are stearic acid with palmitic acid (0.36), linolenic acid with linoleic acid (0.35) and linoleic acid with grain yield per plant (0.53) and palmitic acid (0.50). High, negative and significant correlation was observed for oil content with number of days to maturity (-0.37); oleic acid with palmitic acid (-0.56); grain yield (-0.47) and number of pods per plant (-0.33); linoleic acid with oleic acid (-0.94) and harvest index (-0.35) and linolenic acid with oleic acid (-0.41).

Late sowing: In late sowing high positive and significant correlation was observed for 100-seed weight with number of pods per plant (0.43); grain yield with number of pods per plant (0.46) and 100-seed weight (0.47) and oil content with 100-seed weight (0.49) (Table 3). Other characters showing positive correlations were oil content with grain yield and stearic acid with number of pods per plant. Highly negative and significant correlation was observed for harvest index with number of pods per plant (-0.37), linoleic acid with oleic acid (-0.77) and linolenic acid with oil content (-0.49) and oleic acid (-0.53). Other characters showing negative correlation are grain yield with days to flowering, harvest index with plant height, protein content with days to flowering, stearic acid with number of days to maturity and linoleic acid with palmitic acid. It was observed that values of phenotypic correlation coefficients were relatively lower than that of genotypic correlation coefficients. This may be due to modified effect of environment on character association and genetic level.

Pods per plant had highly significant and positive correlation with grain yield in all the sowing dates. It indicated that pods per plant directly contribute to grain yield and it is the main yield component in soybean. So, selection for pods per plant will be much effective in increasing the yield. Grain yield per plant also had high significant positive association with 100-seed weight in the third sowing. Results of present investigations find support from Mahajan *et al.* (1993) who observed positive correlations of seed yield with pods per plant. Similarly positive significant correlations of number of pods per plant with yield have been reported by Shinde *et al.* (1996), Nehru *et al.* (1999), Onemli (2003) and Mukhekar *et al.* (2004). Grain yield per plant had highly significant positive association with plant height in spring sowing (0.34) and main sowing (0.37). Earlier studies by Dobhal and Gautam (1995) have shown negative correlation of grain yield per plant with plant height, which is contradictory to the present study. Also number of pods per plant was positively correlated with plant height (0.56) in spring sowing and 100-seed weight (0.43) in main sowing. These results were similar to Onemli (2003) findings. Grain yield was positively associated with protein content in spring sowing and oil content in late sowing. These results are contradictory to Shinde *et al.* (1996) and Mello *et al.* (2004), but similar to Dixit and Patel (1984) and Nehru *et al.* (1999). Significant and positive associations emphasize that selection based on these characters would be effective in improvement of grain yield. As regards the association among the quality traits, significant positive correlation was found for linoleic acid and 100-seed weight in spring sowing, with number of pods per plant in spring and main sowing and with palmitic acid in main sowing. So, selection for more number of pods per plant and larger

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Table 1. Correlation coefficients for all possible pair of characters in case of spring sowing

Character	Days to flowering	Plant Height (cm)	No. of pods/ plant	No. of days to maturity	100-seed weight	Grain yield (g/ plan)	Harvest index (%)	Protein content (%)	Oil content (%)	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid
Days to flowering	-	1.09	0.73	0.31	-0.51	0.73	-0.72	0.19	0.48	-0.66	0.14	0.72	-0.40	-0.17
Plant Height (cm)	0.50**	-	0.81	0.24	-0.70	0.54	-0.62	-0.02	0.44	-0.49	0.51	0.31	-0.28	-0.14
No. of pods/ plant	0.36**	0.56**	-	0.18	-0.37	0.75	-0.61	-0.01	0.31	-0.55	-0.44	-0.10	0.28	-0.37
No. of days to maturity	0.17	0.19	0.16	-	0.26	-0.11	-0.48	-0.38	-0.01	0.33	-0.02	-0.29	0.31	-0.35
100-seed weight (g)	-0.25*	-0.21	-0.10	0.09	-	-0.37	-0.21	-0.21	-0.10	0.35	-0.97	-0.34	0.43	-0.23
Grain yield (g/ plant)	0.29*	0.34**	0.69**	-0.05	-0.16	-	-0.48	0.75	0.14	-0.30	-0.43	0.17	-0.05	0.09
Harvest index (%)	0.12	-0.12	-0.31*	-0.27*	-0.03	-0.23	-	-0.28	0.44	-0.43	0.04	0.22	-0.08	0.00
Protein content (%)	0.12	0.04	0.09	-0.23	0.20	0.27*	-0.08	-	-0.32	0.19	-0.52	0.70	-0.61	0.91
Oil content (%)	0.12	0.07	0.22	0.00	-0.26*	0.18	0.08	-0.35**	-	-0.33	0.09	-0.10	0.22	-0.53
Palmitic acid	-0.16	-0.24	-0.37**	0.21	0.06	-0.18	-0.02	-0.09	-0.07	-	0.39	0.02	-0.26	0.41
Stearic acid	0.04	0.04	-0.18	-0.03	-0.12	-0.22	0.27*	-0.12	0.08	0.32**	-	0.53	-0.76	0.41
Oleic acid	0.32**	0.2	-0.09	-0.28*	-0.22	0.15	0.08	0.28*	-0.03	-0.12	0.18	-	-0.91	0.33
Linoleic acid	-0.20	-0.17	0.25*	0.30*	0.25*	-0.06	-0.03	-0.27*	0.12	-0.23	-0.45**	-0.84**	-	-0.62
Linolenic acid	-0.18	0.06	-0.25*	-0.21	-0.12	0.06	-0.04	0.37**	-0.37**	0.18	0.03	0.24	-0.46**	-

The values above diagonal are genotypic correlations and below are phenotypic correlations.
Critical value of r at 5% = 0.25*
at 1% = 0.32**

Table 2. Correlation coefficients for all possible pair of characters in case of main sowing

Character	Days to flowering	Plant Height (cm)	No. of pods/ plant	No. of days to maturity	100-seed weight	Grain yield (g/ plant)	Harvest index (%)	Protein content (%)	Oil content (%)	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid
Days to flowering	-	0.54	0.12	0.36	0.30	0.03	0.21	-0.15	-0.39	0.16	0.14	-0.14	0.10	0.25
Plant Height (cm)	0.31*	-	0.17	0.29	0.27	0.48	0.20	0.38	-0.05	-0.30	0.64	-0.20	0.11	0.58
No. of pods/ plant	0.10	0.21	-	-0.23	0.35	0.37	-0.46	0.75	0.07	0.49	0.50	-0.43	0.41	0.16
No. of days to maturity	0.21	0.16	-0.11	-	-0.01	-0.28	0.14	-0.35	-0.32	-0.55	0.09	0.31	-0.34	-0.01
100-seed weight (g)	0.09	0.18	0.21	0.09	-	0.42	-0.03	0.40	0.23	-0.02	-0.16	0.10	0.01	-0.55
Grain yield (g/ plant)	0.02	0.37**	0.42**	-0.17	0.18	-	0.00	0.43	0.16	0.17	0.20	-0.53	0.60	0.12
Harvest index (%)	0.17	0.18	-0.18	0.11	-0.01	0.05	-	-0.15	0.34	-0.25	0.35	0.34	-0.37	-0.20
Protein content (%)	-0.08	0.12	0.29*	-0.19	0.04	0.10	-0.05	-	-0.07	0.14	0.11	-0.15	0.21	-0.32
Oil content (%)	-0.30*	-0.02	0.18	-0.37**	-0.03	0.16	0.28*	-0.01	-	-0.18	0.46	0.37	-0.38	-0.49
Palmitic acid	0.09	-0.10	0.29*	-0.13	-0.04	0.18	-0.22	-0.04	-0.14	-	0.57	-0.78	0.63	0.34
Stearic acid	0.05	0.21	0.14	0.25*	-0.10	0.11	0.13	-0.02	-0.04	0.36**	-	-0.41	0.12	0.51
Oleic acid	-0.13	-0.13	-0.33**	0.23	0.03	-0.47**	0.31*	-0.09	0.27*	-0.56**	-0.24	-	-0.97	-0.78
Linoleic acid	0.10	0.07	0.31*	-0.25*	0.01	0.53**	-0.35**	0.11	-0.29*	0.50**	0.04	-0.94**	-	0.50
Linolenic acid	0.19	0.26*	0.01	-0.01	-0.10	0.02	-0.20	0.10	-0.25*	0.19	0.25*	-0.41**	0.35**	-

The values above diagonal are genotypic correlations and below are phenotypic correlations.
Critical value of r at 5% = 0.25*
at 1% = 0.32**

Table 3. Correlation coefficients for all possible pair of characters in case of late sowing

Character	Days to	Plant	No. of	No. of	100-	Grain	Harvest	Protein	Oil	Palmitic	Stearic	Oleic	Linoleic	Linolenic

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Table 3. Correlation coefficients for all possible pair of characters in case of late sowing

Character	Days to flowering	Plant Height (cm)	No. of pods/ plant	No. of days to maturity	100-seed weight	Grain yield (g/ plant)	Harvest index (%)	Protein content (%)	Oil content (%)	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid
Days to flowering	-	-0.19	-0.18	0.30	-0.30	-0.50	0.19	-0.51	0.26	-0.08	-0.15	0.17	-0.07	-0.13
Plant Height (cm)	-0.06	-	0.49	-0.16	0.26	0.53	-0.97	0.12	0.06	-0.02	1.27	0.13	-0.35	-0.10
No. of pods/ plant	-0.11	0.20	-	-0.01	0.62	0.36	-1.44	0.13	0.06	0.39	0.69	0.04	-0.19	-0.13
No. of days to maturity	0.26*	0.01	0.00	-	0.02	-0.15	0.25	-0.16	0.04	-0.14	-0.44	0.02	0.10	-0.10
100-seed weight (g)	-0.16	0.19	0.43**	0.05	-	0.72	-0.80	0.12	0.60	0.14	0.22	-0.03	0.11	-0.26
Grain yield (g/ plant)	-0.28*	0.10	0.46**	-0.04	0.47**	-	-1.19	-0.14	0.38	0.01	0.44	-0.36	0.36	0.07
Harvest index (%)	0.00	-0.26*	-0.37**	0.22	-0.10	0.06	-	-0.27	-0.10	-0.93	-1.29	-0.17	0.46	0.11
Protein content (%)	-0.28*	0.08	0.09	-0.05	0.08	0.07	-0.10	-	-0.08	0.00	-0.37	0.04	0.12	-0.19
Oil content (%)	0.21	-0.01	-0.02	0.07	0.49**	0.27*	-0.02	0.00	-	0.01	0.38	0.16	0.21	-0.58
Palmitic acid	0.02	0.06	0.17	0.00	0.05	0.10	-0.11	0.05	0.03	-	0.07	-0.39	0.16	-0.22
Stearic acid	-0.02	0.15	0.26*	-0.25*	0.14	0.18	-0.21	-0.11	0.17	0.04	-	0.59	-0.69	-0.48
Oleic acid	0.10	0.09	0.06	0.01	0.00	-0.20	-0.02	0.04	0.14	-0.15	0.23	-	-0.82	-0.62
Linoleic acid	-0.01	-0.16	-0.15	0.10	0.11	0.21	0.18	0.06	0.17	0.04	-0.31*	-0.77**	-	0.13
Linolenic acid	-0.20	0.00	-0.11	-0.09	-0.18	0.00	0.04	-0.11	-0.49**	-0.03	-0.21	-0.53**	0.09	-

The values above diagonal are genotypic correlations and below are phenotypic correlations
Critical value of r at 5% = 0.25*
at 1% = 0.32**

seed in soybean may increase the linoleic acid, which is an important determinant for soybean oil quality. This would also help in enhancing the nutritive value of soybean oil for food products by reducing the total saturated fatty acids in the oil. Linolenic acid showed significant positive association with protein content in spring and negative association with oleic acid in late and main sowings and with oil content in all the three sowings. Linolenic acid has been observed to be associated with undesirable flavour and poor stability of oil. Palmitic acid was positively correlated with stearic acid in spring and main sowings. Present studies showed that protein content was highly negatively associated with oil content in spring and showed no correlation in main and late sowings. Wang and Yu (1988) reported that lines with high oil content tend to have low protein content.

As results shown in the study, the correlation of grain yield with number of pods was high in all the sowing dates where as with plant height was significant in spring and main sowings only. So while selecting for yield in spring and main sowing both plant height and number of pods are important while selecting for high yielding genotypes during late planting only number of pods are needed to be considered.

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Assessment of Genotype X Environment Interactions and Stability Analysis in Soybean [*Glycine max* (L.) Merrill]

S.D. Tyagi, Jyoti Sethi and Vikrant Tyagi[1]*

Department of Agricultural Botany, Kisan (P.G.) College, Simbhaoli, Ghaziabad-245207, India
[1]Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, 141004, India
**E-mail: Vikranttyagi97@gmail.com*

Abstract: Genotype x environment interaction studies in soybean [*Glycine max* (L.) Merrill] were undertaken by growing fourty genotypes in eight different environments. The analysis of variance revealed highly significant differences due to genotypes, environments and genotype x environment interactions for all the traits. Significant environment (linear) variances were observed for all the characters. G x E (linear) variances were highly significant for days to maturity and protein content. Genotype MACS-47 had highest mean yield, average stability and was found to be stable over the environments for seed yield. Pusa-37 in addition to having stability for early maturity also had highest protein content and average response to environments.

Key Words: Soybean, stability, genotype x environment interaction

Genotype-environment interactions are of great significance in any breeding programme. Of late, much emphasis has been laid on understanding the nature of genotype-environment interactions and the appropriate techniques for their analysis. Most of the available analytical methods are primarily based on the demonstration that the genotypic performance has a linear relationship with the environmental index and the deviation from linearity represents the instability of the genotype. Such a study in soybean would be of immense value in isolating suitable genotypes for their better performance in different environments and to use them in a breeding programme.

MATERIAL AND METHODS

An experiment was conducted with 40 (37 indigenous and 3 exotic) genotypes of soybean in randomized completed block design experiment with three replications during spring and rainy season at Research Farm, Kisan (P.G.) College, Simbhaoli (Ghaziabad), Uttar Pradesh. In each of the eight environments (2 season x 2 sowing dates x 2 years), each genotype was assigned to two row plots of 3.0 m length with inter and intra-row spacing of 30 cm and 10 cm, respectively. Recommended package of practices were followed to raise a good crop. Data were collected on five randomly selected competitive plants from each plot for days to maturity, seed yield per plant and per cent protein content. The protein content was estimated as outlined in A.O.A.C. (1975). The data were statistically analyzed and the genotypes were assessed for their stability of performance over environments following the method described by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

The pooled analysis of variance indicated significant differences among genotypes, environments, and G x E interactions for all traits (Table 1). These results suggested that genotypes interacted significantly with the environments. The linear variance due to G x E was highly significant for all the characters except seed yield/plant suggesting that major portion of G x E interaction can be attributed to non-linear components in respect to these traits, while for seed yield linear component was also important. The more pronounced linearity over non-linearity for days to maturity and protein content indicated that variations among the genotypes could largely be explained by differences in regression value. This observation suggests that accurate prediction of the phenotypic performance of the genotype can be done for these two characters. Similar observations have also been reported by Dhillon *et al.* (2009) and Jai Dev *et al.* (2009). Significant mean sum of squares due to environments (linear) against pooled deviation for all the traits were indicative of considerable differences among the environments and their pre-dominant effects on these characters. The mean squares due to pooled deviation from regression were also significant indicating that a high degree of non-linearity existed in the genotype-environment relationship.

The estimates of three parameters *viz.*, mean, regression coefficient (bi) measuring response and the deviation (S^2di) measuring stability have been presented in Table 2. Different stable genotypes for various characters were observed to have different magnitude of response (bi) to the environments. This showed that the existence of two

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Table 1. Pooled and stability analysis of variance (MS) of different traits studied for 40 soybean genotypes over 8 environments

Source of Variation	d.f.	Mean Square		
		Seed yield	Protein content	Days to maturity
Genotypes (G)	39	24.54**+	129.39**+	103.57**+
Environment (E)	7	118.83**+	23.23**+	772.14**+
G x E	273	1.97**	4.29**	7.78**
Environment + (G+E)	280	4.90**+	4.76**+	50.43**+
E (linear)	1	831.89**+	162.46**+	5404.85**+
G x E (linear)	39	1.96**	11.32**+	15.09**+
Pooled deviation	240	1.93**	3.04**	6.39**
Pooled error	624	0.46	2.18	4.17

*P = 0.05, ** P = 0.01

independent genetic systems controlling the inheritance of stability and the responsiveness. Therefore, it appeared possible to incorporate the stability with any kind of desired response for all the important attributes in a single genotype through the appropriate breeding techniques. The independence of genetic systems for these two parameters in soybean have also been reported by many workers (Saikia *et al.*, 1994; Singh *et al.*, 2001).

The mean performance of the genotypes over the environments for seed yield revealed a wider range from 6.50 g (MACS-58) to 12.87 g (MACS-47). According to Eberhart and Russell (1966) an ideal variety is one with high mean performance, average responsiveness to environments and high stability (bi=1). The non-significant S^2di indicates the predictability of a genotype in a given environment. The stability parameters indicated that genotype MACS-47 had highest mean yield (12.87 g), average response to environments (b=1) and non-significant deviation from regression line, therefore, this genotype was found to be stable over the environments. This indicated that this genotype could be formed as high yielding, highly stable and could be recommended for general cultivation. The genotypes Pusa-16, MACS-2, MACS-450 and JS-335 had high mean, above average stability (b<1) and non-significant deviation from regression, indicating predictable performance of these genotypes and could be perform better under poor environments with predictable performance. Genotypes PK-308, Alankar and JS-22 had high mean yield, below average stability (b>1) and non-significant deviations from regression, thus, these three genotypes would perform better under favourable environment with predictable performance. Genotypes, Pusa-40, Pusa-20 and MACS-58 with high mean yield, above average stability (b<1) and highly significant deviations from regression, would perform better under poor environments but with unpredictable performance. Genotype Indra soya-9 had high mean, below average stability (b>1) and highly significant deviation from regression, therefore, this genotype was found to be suitable for favourable environments though its performance was unpredictable. Genotypes MACS-2 and Bragg having high mean, below average stability (b>1) with non-significant deviations from regression line was found to be suitable for favourable environments with predictable performance.

The mean performance of genotypes for protein content over the environments revealed that it ranged from 29.44 per cent in JS-335 to 44.62 per cent in PK-1347. The stability analysis revealed that genotypes PK-1347, Pusa-16, Pusa-20, SL-96, PK-416 and JS-22 with high mean, above average stability (b<1) and non-significant deviations were found to be suitable under poor environments with predictable performance. However, genotypes SL-295 and Alankar had high protein content and non-significant deviations from regression but the "bi" value was significantly lower than unity, thus, these two genotypes would perform better under favourable environments with predictable performance. The released variety Pusa-37 had high protein content (44.08) average response to environments (b=1) and non significant deviations from regression line, which makes this variety stable over the environments.

The mean performance of genotypes for days to maturity over the environments ranged from 92.8 days in Pusa-37 to 109.08 days in Gaurav with population mean 102.29 days. All the genotypes were non-significant as per the "bi" values except genotypes MACS-124, JS-80-21, MACS-58, Shilajeet, Pusa-16, Bragg, SL-637, MACS-2, Birsa soya and Punjab-1. The variety Pusa-37 matured earlier (92 days) and showed average response (bi=1) with non-significant deviation from regression line. However, this variety being the poorest in seed yield, could only be used as a donor of stability and average responsiveness for maturity and protein content for a population, while other is giving a good seed yield.

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Table 2. Stability parameters for the considered plant traits

Sl.	Genotypes	Days to maturity			Seed yield			Protein content		
		Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
1	PK-1347	97.88	1.25	1.84	6.63	0.58	0.23	44.62**	0.65	-1.90
2	JS 7105	103.29	0.75	10.43	6.56	0.47	0.86	55.08	0.59	-2.44
3	Lee	105.12	0.70	1.46	7.24	0.63	0.46	43.44**	2.39*	9.56
4	MACS-124	101.12	1.51	7.89	7.48	0.79	1.20	36.66	0.64	4.43
5	MACS-61	97.88	1.27	20.22*	7.41	0.63	0.50	33.05	0.23	-1.19
6	GS-2	102.12	0.78	4.84	9.70	0.99	0.36	35.54	0.10	-2.22
7	Pusa-16	99.12	1.48	17.30	11.27**	0.86	0.23	44.62**	0.32	-1.11
8	Pusa-24	97.62	1.39	12.63	7.94	0.78	0.76	35.94	0.31	-1.76
9	Pusa-37	92.08	0.88	1.38	9.85	1.20	1.70*	44.08**	0.98	-2.37
10	Pusa-40	103.50	0.98	0.14	10.85	0.77	6.23**	36.56	0.43	-2.49
11	Pusa-20	104.50	0.71	1.72	10.81	0.90	5.34**	39.16**	0.74	-1.59
12	Pusa-22	105.88	1.02	2.72	10.13	0.63	5.45**	40.02**	2.02*	-1.94
13	SL-295	103.62	1.02	14.63	9.80	0.42	1.31	39.06**	0.07	-1.67
14	MACS-58	100.50	0.59	-0.58	10.91*	0.48	6.75**	32.26	1.49	-2.30
15	Bragg	101.50	0.55	5.46	10.53	1.37	0.79	38.83**	1.22	-2.48
16	SL-96	105.00	0.99	0.49	10.30	1.34	1.10	40.79**	0.82	-2.11
17	SL-637	103.29	0.35	2.49	10.39	1.21	3.52*	35.90	0.30	-2.57
18	PK-416	108.12	0.72	-0.99	10.61	1.03	2.77*	39.71**	0.70	-2.05
19	MACS-2	103.71	0.42	10.40	11.23**	0.92	1.47	41.87**	4.33**	7.06
20	Birsa soya	105.50	0.35	-0.54	12.08**	1.28	0.53	41.21**	3.00*	8.99
21	Punjab-1	106.12	0.50	5.84	10.47	1.28	2.04*	39.29**	5.99**	18.96
22	PK-308	106.88	0.74	1.09	11.10**	1.22	0.97	40.77**	2.48*	11.38
23	Gaurav	109.08	0.78	0.71	10.32	1.48	4.74**	32.47	3.52*	2.86
24	Indra Soya-9	107.38	0.99	-0.48	12.24**	1.46	1.79**	36.28	1.12	-2.65
25	JS 80-21	100.88	1.58	3.96	10.07	1.29	1.83**	38.62**	2.31*	-2.09
26	Ankur	100.00	1.27	1.55	10.04	1.19	4.56**	37.60**	1.37	-2.64
27	PS 1029	98.88	0.85	-0.37	6.99	0.87	0.42	38.90**	5.43*	14.90
28	MACS-450	101.12	1.19	0.34	10.84*	0.82	1.12	31.29	1.64	-1.65
29	MACS-47	102.88	1.24	1.37	12.87**	1.08	0.57	30.54	0.45	-2.22
30	JS 335	103.33	1.07	1.85	12.18**	0.94	0.85	29.44	0.44	-2.41
31	Alankar	105.29	1.18	0.97	11.39**	1.43	0.58	42.19**	0.10	-1.24
32	PK-1042	94.75	1.24	5.37	9.11	1.19	0.77	33.49	1.03	-2.54
33	VLS-21	101.12	1.23	6.38	7.19	0.95	0.07	34.12	0.04	-2.01
34	MARC-2	103.46	1.13	4.69	10.42	1.59	5.82**	38.92**	1.11	-1.66
35	PK-472	103.88	1.17	2.47	10.36	1.02	0.56	29.91	-0.22	-1.21
36	JS 22	105.75	1.16	1.98	11.88**	1.27	0.47	39.98**	0.56	-2.49
37	MACS-58	100.25	1.70	25.59*	6.50	0.67	0.53	36.26	0.93	-2.39
38	Shilajeet	102.12	1.20	3.08	8.42	0.97	0.83	31.65	1.49	-2.49
39	ADT-1	96.12	1.03	15.90	8.03	0.77	0.18	33.15	1.01	-0.92
40	MACS-2	104.25	1.03	3.88	9.74	1.23	1.40	34.90	0.94	-2.14
Mean		102.29			9.79		37.10			
CV %		1.48			4.93			5.46		

Mean: Mean observation for each genotype in all environments, bi: regression coefficient and S2di: deviation mean square (Eberhart and Russell, 1966)

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Table 3. Soybean genotypes identified for stability and adaptability

Characters	Number of genotypes idenfied for			
			Specific adaptability	
	Stableness	General adaptability	Better environment	Poor environment
	S^2di~0	(S^2di~0, b~1)	(S^2di~0, bi>1)	(S^2di~0, bi<1)
Seed yield/plant (g)[x e"μ]	8	1 MACS-47	3 PK-308, Alankar, JS-22	4 Pusa-16, MACS-2, MACS-450, JS-335
Protein content [x e"μ]	9	1 Pusa-37	2 MACS-2, Bragg	6 PK-1347, Pusa-16, Pusa-20, SL-96, PK-416, JS-22
Days to maturity [x d"μ]	1	1 Pusa-37	-	-

Overall (Table 3), the genotype MACS-47 had high mean seed yield and was found to be stable over the environments and therefore, could be used in the breeding programme for the development of high yielding stable genotype over the environments for future use. Pusa-37 was observed to be stable for protein content and early maturity over the environments, thus this could be used as one of the parents for developing varieties for high protein content and early maturity.

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Determination of Genetic Variability, Correlation and Path Analysis for Yield Advancement in Fennel (*Foeniculum vulgare* Mill.)

Sunil Kumar Rawat, Sanjay Kumar* and V.K. Pandey

Department of Applied Plant Science (Horticulture),
Babasaheb Bhimrao Ambedkar University,Lucknow-226025(UP)
**E-mail: sanjay123bhu@gmail.com*

Abstract: An experiment was conducted to study the determination of genetic variability, correlation coefficient and path analysis for yield advancement in fennel were studied for 13 diverse genotypes. Considerable amount of variation were recorded for all the characters. The maximum genotypic coefficient of variation (GCV) was recorded for yield per plant (40.27) followed by seed yield (q/ha^{-1}) (32.40), weight of seed per umbel (27.12), number of umbellets per umbel (17.47) and number of seeds per umbel (16.88). High heritability coupled with high genetic were recorded for number of seeds per umbel, yield per plant, plant height, number of umbel per plant and number of branches per plant.

Key words: Genetic variability, correlation, path analysis and fennel

Fennel (*Foeniculum vulgare* Mill.) belongs to the family Apiaceae is a well aromatic and medicinal herb. The leading country recently came up are Egypt and China. The major fennel producing states in India are Rajasthan, Gujarat and Uttar Pradesh. It is seasonal spices and medicinal crop of the country. Fennel takes 170-180 days to mature, harvesting is done before fruits are fully ripe and completes in three picking at an interval of 10-12 days. Dried fruits have pleasant aromatic taste and used for flavouring sauces, soups, meat dishes, other confectionary purposes and preparations of pickle. They are carminative. Seeds are useful in disease of chest spleen, kidney and have vermicidal property against hookworm. Seeds contain 0.7-1.2% volatile oil and used in flavouring the culinary products. Fennel is an important aromatic and medicinal herb but very little information is available on its genetic potential for yield and yield attributing traits. Therefore, in the present investigations effort was made to investigate the extent of genetic variability to access interaction among the twelve characters and to understand the nature of direct and indirect effect of those characters on yield.

MATERIAL AND METHODS

The experiment was carried out at Horticultural Research Farm, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University, Vidya-Vihar, Rae Bareli Road, Lucknow-226025(U.P.). Thirteen genotypes of fennel were used as experimental materials i.e. Pant Madhurika, Hissar Swarup, Azad Saunuf, Rajendra Saunuf, Gujarat Fennel-11, Rajasthan Fennel-125, CO-1, Rajasthan Fennel-101, Rajasthan Fennel-143, Rajasthan Fennel-178, Gujrat Fennel-1, Gujrat Fennel-2 and Azad Fennel-1. The experiment was laid out in a Randomized Block Design with three replications. All the recommended cultural practices were adopted to raise a healthy growth of the crop. The row to row and plant to plant spacing were maintained at 45 x 25 cm, respectively. The observation were recorded form randomly selected five plants form each genotypes in each replication for day to fifty percent germination, plant height (cm), days to fifty percent flowering, number of branches per plant, number of umbel per plant, number of umbellets per umbels, days to maturity, number of seed per umbel, 1000-seed weight, weight of seed per umbel (g), yield per plant and seed yield (q/ha $^{-1}$). The estimates of heritability and genetic advance were calculated by the methods of Honson *et.al* (1956) and Johnson *et.al* (1955), respectively. Genotypic and phenotypic coefficient of variation were calculated by the method suggested by Burton and De-Vane (1953). Correlation coefficient and path coefficient levels were calculated by Al-Jibouri *et.al*. (1958) and Deway and Lu (1959), respectively.

RESULTS AND DISCUSSION

Analysis of variance revealed the presence of significant variability for all the characters studied (Table-1). The extent of variability in respect of twelve characters of 13 genotypes measured in terms of range, mean, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and expected genetic advance as percent of mean indicated. Considerable amount of variation was recorded for all the characters (Table-1). Weight of seed per umbel and 1000-seed weight ranged from 0.58 to 1.52 (g) and 4.38 to 6.07 (g), respectively. Days to fifty percent germination, plant height (cm), number of branches per plant, days to fifty percent flowering, number of umbel per plant, number of umbellets per umbel, number of seed per

Table 1. Analysis of Variance, Range, General mean, GCV and PCV, Heritability and Genetic advance for 12 characters in fennel genotypes

Source of variance	Replications	Treatments	Errors	Range	General	GCV	PCV	Heritability	Genetic advance

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Table 1. Analysis of Variance, Range, General mean, GCV and PCV, Heritability and Genetic advance for 12 characters in fennel genotypes

Source of variance	Replications	Treatments	Errors	Range (Min.-Max.)	General mean	GCV (%)	PCV	Heritability (%)	Genetic advance (as percent of mean)
D.F.	2	12	24						
Days to 50% germination	75.53	70.25**	87.29	9.61- 13.25	11.88	7.18	8.47	71.80	1.49
Plant height (cm)	73.47	95.13**	40.49	97.02-123.43	108.65	7.43	9.19	65.30	13.43
Number of branches plant $^{-1}$	0.83	10.38**	10.53	30.66-49.24	39.99	12.27	12.85	91.20	9.65
Days to 50% flowering	0.11	30.61**	9.18	86.81-105.33	93.81	9.72	6.87	69.40	9.21
Number of umbels per plant	0.02	28.35**	3.75	31.01-50.25	41.05	13.86	14.90	86.50	10.90
Number of umbellate per umbel	10.13	75.32**	0.22	18.41-32.04	23.87	17.47	18.79	86.40	7.98
Number of seed per umbel	0.13	95.11**	0.13	442.33-742.33	604.92	16.88	18.35	84.60	193.56
Weight of grains per umbel (g)	0.17	1.56**	1.31	219.89-229.89	222.51	1.16	1.84	39.60	3.34
Test weight (g)	0.65	0.24**	7.14	4.38-6.07	5.02	10.03	10.53	90.80	0.99
Days to maturity	0.86	0.19**	5.76	0.58-1.52	0.88	27.12	27.89	94.60	0.48
Yield plant $^{-1}$ (g)	100.81	121.49**	19.42	17.89-98.31	64.30	40.27	40.93	96.80	52.47
Seed yield (q/ha)	20.33	85.48**	0.85	8.65-15.69	11.36	32.40	34.55	88.00	7.11

*, ** Significant at 5% and1%

umbel, Weight of grain per plant, Test weight (g), days to maturity and seed yield (q/ha^{-1}) varied from 9.61 to 13.25, 97.02 to 123.43, 30.66 to 49.24, 86.81 to 105.33, 31.01 to 50.25 , 18.41 to 32.04, 442.33 to 742.33 , 219.89 to 229.89,4.38 to 6.07 ,0.58 to 1.52 and 8.65 to 15.69, respectively. The PCV were higher than their respective GCV for all the characters, indicating the role of environment in the expression of genotype. The maximum PCV and GCV estimates were recorded followed by seed yield, weight of seed per umbel and number of seeds per umbel, respectively.

Heritability estimates were high for yield per plant (96.80%) followed by weight of seed per umbel, number of branches per plant, 1000-seed weight, seed yield, number of umbel per plant, number of umbellets per umbel and number of seed per umbel, moderate for days to fifty percent germination, days to fifty percent flowering and plant height and while, least was recorded for days to maturity. Heritability and genetic advance are important selection parameters. Heritability estimates along with genetic advance are normally more useful in predicting the gain under selection than heritability estimates alone. However, it is not necessary that a character showing high heritability will also exhibit high genetic advance. Estimates of heritability will also give some idea about the gene action involved in the various polygenic traits (Johnson *et. al* 1955). High expected genetic advance were observed for number of seed per umbel (193.56) followed by yield per plant (52.47), plant height (13.43), number of umbel per plant (10.90) and number of branches per plant (9.65).

Estimates of correlation coefficient among yield contributing characters at genotypic and phenotypic levels are presented in Table-2. In general, magnitude of the genotypic correlation were higher than their corresponding phenotypic correlation for most of the characters, which revealed that the phenotypic expression of the correlation is reduced under the influence of environment, although there is a strong inherent association between various characters. Seed yield (q/ha^{-1}) was found to be positively and significantly correlated with days to fifty percent flowering (0.540, 0.560) and days to fifty percent germination (0.491, 0.494) both at phenotypic and genotypic level, respectively. Weight of seed per plant had positive and significant correlation with 1000-seed weight, days to maturity (0.381, 0.644) and days to fifty percent flowering both at phenotypic and genotypic level, respectively. 1000-seed weight had positive and significant correlation with days to fifty percent flowering both at phenotypic and genotypic level, respectively. Days to maturity had positive and significant with days to fifty percent flowering both at phenotypic and genotypic level, respectively. Number of seeds per umbel

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Table 2. Estimation of phenotypic and genotypic correlation coefficient for 12 characters in fennel

Genotypes		Plant height (cm)	Number of branches per plant	Days to fifty percent flowering	Number of umbels per plant	Number of umbellets per umbels	Number of seed per umbel	Days to maturity	Test weight (g)	Weight of seed per umbel(g)	Yield per plant	Seed yield (qha^{-1})
Days to 50% germination	P	-0.371**	0.497**	-0.251	-0.177	-0.268	-0.509**	0.094	0.090	0.037	0.618**	0.491**
	G	-0.549**	0.568**	-0.241	-0.240	-0.278	-0.382	0.038	0.083	0.007	0.773**	0.494**
Plant height (cm)	P		0.045	-0.025	-0.045	0.221	0.605**	0.029	0.033	0.260	0.617**	0.167
	G		-0.026	-0.101	-0.157	-0.311**	0.799**	0.014	0.062	0.357**	0.731**	0.226
Number of branches per plant	P			-0.065	0.618**	0.448**	-0.019	-0.217	0.227	-0.004	0.086	0.081
	G			-0.038	0.673**	0.491**	0.017	-0.328**	0.236	0.021	0.076	0.081
Days to fifty percent flowering	P				0.446**	0.317**	0.114	0.460**	0.451**	0.464**	0.197	0.540**
	G				0.617**	0.495**	0.142	0.581**	0.577**	0.573**	0.208	0.560**
Number of umbels per plant	P					-0.125	0.144	0.058	0.006	-0.116	0.063	0.271
	G					-0.183	0.210	0.115	0.081	-0.108	0.063	-0.489**
Number of umbellets per umbels	P						0.449**	0.405**	-0.228	-0.283	0.155	0.123
	G						0.556**	0.691**	-0.241	-0.326**	0.168	0.121
Number of seed per umbel	P							0.215*	-0.054	0.164	0.533**	0.185
	G							-0.396**	-0.075	0.177	0.580**	0.207
Days to maturity	P								-0.166	0.381**	-0.069	-0.062
	G								-0.227	0.644**	-0.042	0.106
Test weight (g)	P									0.308**	-0.147	0.112
	G									0.387**	-0.163	0.108
Weight of seed per umbel(g)	P										0.462**	0.151
	G										0.492**	0.149
Yield per plant (g)	P											0.571**
	G											0.611**

Table 3. *Direct and indirect effect of various characters on seed yield (q/ha^{-1})*

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Table 3. Direct and indirect effect of various characters on seed yield (q/ha^{-1})

Genotypes	Days to germination	Plant height (cm)	Number of branches	Days to fifty percent flowering	Number of umbels per plant	Number of umbellets per umbels	Number of seed per umbel	Days to maturity	Test weight (g)	Weight of seed per umbel (g)	Yield per plant	Phenotypic correlation with seed yield (q/ha^{-1})
Days to germination	**0.012**	0.085	0.071	-0.076	-0.034	0.005	0.047	-0.006	0.040	-0.007	-0.551	0.491
Plant height (cm)	-0.005	**-0.229**	-0.009	-0.008	-0.009	0.004	-0.092	-0.002	0.015	-0.050	0.551	0.167
Number of branches per plant	-0.005	-0.010	**-0.192**	-0.020	0.120	-0.008	0.003	0.015	0.101	0.001	0.077	0.081
Days to fifty percent flowering	0.003	0.006	0.013	**0.302**	0.086	0.006	-0.017	-0.011	-0.168	0.072	0.176	0.540
Number of umbels per plant	-0.002	0.010	-0.119	0.135	**3.746**	-0.002	-0.022	-0.004	0.003	0.022	0.056	0.271
Number of umbellets per umbels	-0.003	-0.051	0.086	0.096	-0.024	**0.633**	-0.068	-0.021	-0.102	0.054	0.138	0.123
Number of seed per umbel	-0.004	-0.139	-0.004	0.034	0.028	0.008	**3.989**	-0.015	-0.024	-0.031	0.475	0.185
Days to maturity	0.001	-0.007	0.042	0.048	0.011	0.005	-0.033	**-2.449**	-0.074	0.078	-0.061	-0.062
Test weight (g)	0.001	-0.007	-0.044	-0.114	0.001	-0.004	0.008	0.011	**0.446**	-0.054	-0.131	0.112
Weight of seed per umbel(g)	0.001	-0.060	0.001	-0.113	-0.022	-0.005	-0.025	0.026	0.128	**-0.192**	0.412	0.151
Yield per plant (g)	-0.008	-0.141	-0.016	0.059	0.012	0.003	-0.081	0.005	-0.065	-0.089	**0.892**	0.511

Residual Effect = 0.350

had positive and significant correlation with number of umbellets per umbel and plant height both at phenotypic and genotypic level, respectively. Number of umbellate per umbel had positive and significant correlation with days to fifty percent flowering (0.317, 0.495) and number of branches per plant (0.448, 0.491) both at phenotypic and genotypic level, respectively. Number of umbels per plant had positive and significant correlation with days to fifty percent flowering (0.446, 0.617) and number of branches per plant (0.618, 0.673) both at phenotypic and genotypic level, respectively and number of branches per plant had positive and significant correlation with days to fifty percent germination (0.497, 0.568) both at phenotypic and genotypic level, respectively.

Path coefficient analysis showed at the phenotypic level (Table-3) that the number of seed per umbel (3.989) had highest direct effect on seed yield (q/ha^{-1}) followed by number of umbels per plant, yield per plant, number of umbellets per umbel, 1000-seed weight and days to fifty percent flowering 2). High positive direct effect of seed per umbel was the main cause of its positive association with seed yield (q/ha^{-1}). Residual effect of the path analysis was very low (0.35) revealed that maximum variability has been taken by traits considered in study.

On the basis of present findings, it can be concluded that, it could be inferred that the most of the traits viz., number of seed per umbel, yield per plant, plant height, number of umbel per plant and number of primary branches per plant are under. The additive gene effects and hence, selection for these traits may result in improvement of supervisor genotypes in fennel.

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Indian Journal of Ecology

Potential Use of Distillery Industry Byproducts on Nutrient and Yield Aspects of Multicut Fodder Sorghum

P. Thangavel[1], P. Latha[1], K. Arulmozhiselvan[2] and K. Velayudham[3]

[1]Department of Environmental Sciences, [2]Department of Soil Science & Agricultural Chemistry, [3]Directorate of Crop Management Studies, Tamil Nadu Agricultural University, Coimbatore - 641 003, Tamil Nadu, India.

Abstract: A field investigation was carried out during 2009 to 2010, Research and Development Farm M/s. Bannari Amman Sugars Distillery Division Ltd, Ealur, Sathyamangalam, Erode to assess the performance of multicut fodder sorghum by utilizing distillery industry byproducts *viz.*, distillery spentwash, biocompost and spentwash ash. Treatments involved are distillery spentwash @ 37.5 and 50 kilo litre ha^{-1} at full and split dose, biocompost @ 5.0 tonnes ha^{-1} and spentwash ash @ 400 kg ha^{-1} with recommended dose of fertilizers and the parameters were assessed at 12th, 26th, 39th and 52nd weeks after planting. Results of the field experiment revealed that the application of spentwash @ 37.5 kilo litre ha^{-1} at full dose with recommend dose of nitrogen and phosphorus increased the quality and nutrient parameters and green fodder yield over recommended dose of fertilizer.

Key Words: BDS, biocompost, spentwash ash, soluble protein, nutrients, green fodder yield.

Distillery spentwash is a nutrient rich liquid organic waste obtained from molasses based distillery industries after biomethanation process and it is the carrier of huge amounts of nutrients and organic matter. Approximately 40 billion litre of wastewater is generated per annum from 319 distilleries in the country (Kanimozhi and Vasudevan, 2010). The raw spentwash contains nutrients, organic matter and plant growth promoters namely gibberellic acid and indole acetic acid Biocompost is being prepared by using pressmud and distillery spentwash at the ratio of 1:2.5 and is used as a source of nutrients with a potential of increasing crop production on sustainable manner. The distillery spentwash contains about 1.2 per cent of potassium but this concentration is increased to the range between 10 and 18 per cent, when it is ignited into ash (Jadhav *et al.*, 2010). Forage crops require high amount of N and K and are the better choice towards assessing the nutrient potential of spentwash since it is rich in K and N (Galavi *et al.*, 2009). Keeping this in view, the present study was made to assess the performance of distillery industry byproducts on growth and quality of multicut fodder sorghum.

MATERIAL AND METHODS

The BDS was collected from the distillery unit of M/s. Bannari Amman Sugars Ltd., Periyapuliyur, Erode district, Tamil Nadu and analyzed for its physico-chemical properties by standard procedures (APHA, 1998). Biocompost is being prepared and marketed by M/s. Bannari Amman Sugars Ltd., Ealur and analyzed for its physico - chemical properties. Spentwash ash is being produced by M/s. Bannari Amman Sugars Ltd., Distillery division, Alakangi, Nanjangud, Karnataka and analyzed for its physico - chemical properties. BDS was dark brown colour and a neutral pH (7.42) with high EC (32.5 dS m^{-1}), BOD (6,545 mg L^{-1}) and COD (34,476 mg L^{-1}). It contains highest K (8,376 mg L^{-1}) followed by N (2,116 mg L^{-1}), Ca (2,072 mg L^{-1}), Mg (1,284 mg L^{-1}) and very low content of P (52.8 mg L^{-1}). The biocompost showed a neutral pH (7.26) and 1.74 dS m^{-1} EC with 15.42 per cent organic carbon content. Among the nutrients, the K content was highest (4.08 %), followed by Ca (3.72 %), Mg (2.46 %), P (2.06 %), Na (1.54 %) and N (1.24 %). The spentwash ash was alkaline nature (pH 8.96) with high EC (17.8 dS m^{-1}) and no organic carbon and N content. Among the nutrients, the K content was the highest (10.25 %), followed by Ca, Mg and Na (3.16, 2.54 and 0.65 %), respectively.

The field experiment was conducted during 2009 to 2010 at Ealur, Erode, Tamil Nadu. The location comes under the soil series of Irugur with the subgroup of *Typic Ustorthent* under the soil order Entisol. The soil texture of the experimental site was sandy loam, neutral pH (7.24), non saline (0.28 dS m^{-1}) and rich in organic carbon (3.56 g kg^{-1}). With regard to nutrient status, the soil was low in N (118.5 kg ha^{-1}), medium in P (19.2 kg ha^{-1}) and K (248 kg ha^{-1}). Different doses of BDS, biocompost and spentwash ash along with inorganic fertilizers using multicut fodder sorghum as test crop has been tried. The experiment was laid out in Randomized Block Design with three replications; 45 kg of CO (FS) 29 seed sown with the spacing of 30 x 10 cm. The treatment consisted of T_1 - Recommended dose of NPK (RD), T_2 - Biocompost @ 2.5 t ha^{-1} + RD of NP, T_3 - Spentwash ash @ 400 kg ha^{-1} + RD of NP, T_4 - BDS @ 37.5 kilo litre ha^{-1} at full dose + RD of NP, T_5 - BDS @ 37.5 kilo litre ha^{-1} at split dose (basal 40 % and 10 % after each harvest)

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+ RD of NP, T_6 - BDS @ 50 kilo litre ha^{-1} at full dose + RD of NP, T_7 - BDS @ 50 kilo litre ha^{-1} at split dose + RD of NP.

Spentwash was applied as per the treatment and incorporated into the soil at 30 days before planting in order to reduce the BOD and COD. Biocompost and spentwash ash were applied as basal. Recommended dose of nitrogen at 90 kg ha^{-1} as urea, phosphorus at 40 kg ha^{-1} as single super phosphate and potassium at 40 kg ha^{-1} as muriate of potash was applied. The first harvest was done on 90th days after planting, the crop was allowed for ratooning at 55 days intervals by supplementing N as top dress at the rate of 45 kg ha^{-1}.

The plant samples collected from the field at 12th, 26th, 39th and 52nd WAP coinciding 1st, 3rd, 5th and 7th harvest were dried in hot air oven at 65°C to determine the moisture percentage. The total chlorophyll and carotenoid content were estimated by adopting the procedure of Yoshida *et al.* (1971), reducing sugar content was determined by Somogyi method (Nelson, 1944) and soluble protein content was determined by the procedure described by Lowry *et al.* (1951). The oven dried samples were powdered in Wiley mill attached with stainless steel blades and analyzed for its nutrient content by adopting the standard methods. The four harvest values were cumulated and mean value was presented in Tables. Each harvesting was made at above the ground level in each plot and the total green biomass was weighed and expressed in t ha^{-1}. The data were analyzed statistically and the treatment means were compared at 5% probability level.

RESULTS AND DISCUSSION

Effect of Distillery Industry Byproducts on Physiological Parameters

BDS and biocompost applied plots showed there was improvement in nutrient status of N, P, K, pH, EC, and OC compared to initial status of soil (Table 1).

Application of BDS and biocompost on multicut fodder sorghum had significant influence on the physiological parameters *viz.*, total chlorophyll, carotenoid, reducing sugar and soluble protein compared to spentwash ash and RD (Table 2). Among the treatments, BDS @ 37.5 kilo litre ha^{-1} at full dose + RD of NP registered the highest total chlorophyll (2.81 mg g^{-1}), carotenoid (0.56 mg g^{-1}), reducing sugar (0.73 %) and soluble protein (28.7 mg g^{-1}), which was at par with BDS @ 50 kilo litre ha^{-1} at full doses + RD of NP and the lowest was recorded by RD, which was at par with spentwash ash @ 400 kg ha^{-1} + RD of NP. The productivity of crop depends on photosynthesis and partitioning of assimilates to the economically important parts. The increased content of total chlorophyll and carotenoid was due to the application of BDS. This reflected the high manurial potential of the distillery effluents (Sivasankari, 2009). Plant cells might have retained higher water potential with the application of BDS, which might have prevented protein degradation metabolism and enhanced the soluble protein synthesis by activating enzyme activity (Koach and Mengel, 1977).

Effect of Distillery Industry Byproducts on Nutrient Parameters

Application of BDS and biocompost had significantly influenced the nutrient parameters of multicut fodder sorghum compared to recommended dose of fertilizer and spentwash ash (Table 2). Among the treatments, BDS @ 37.5 kilo litre ha^{-1} at full dose + RD of NP registered the highest nutrient content *viz.*, 1.37, 2.59, 0.46, 0.68 and 0.44 per cent of N, K, Na, Ca and Mg, respectively, which was at par with BDS @ 50 kilo litre ha^{-1} at full dose + RD of NP. In phosphorus, biocompost @ 2.5 t ha^{-1} + RD of NP recorded the highest content of 0.33 per cent which was at par with BDS @ 37.5 kilo litre ha^{-1} at full dose + RD of NP and BDS @ 50 kilo litre ha^{-1} at full dose + RD of NP. The recommended dose of fertilizers recorded that the lowest nutrient content

Table 1. Effect of distillery industry byproducts on initial and after harvest of multicut fodder sorghum field soil

Treatments	pH	EC(dS m^{-1})	OC (g kg^{-1})	Available nutrient (kg ha^{-1})		
				N	P_2O_5	K_2O
RD	7.29	0.24	3.34	119	21.8	210
Biocompost @ 2.5 t ha^{-1} + RD of NP	7.34	0.31	3.71	138	28.9	263
Spentwash ash @ 400 kg ha^{-1} + RD of NP	7.31	0.27	3.37	121	22.2	221
BDS @ 37.5 kilo l ha^{-1} at full dose + RD of NP	7.39	0.38	3.8	143	25.0	281
BDS @ 37.5 kilo l ha^{-1} at split dose + RD of NP	7.24	0.29	3.55	125	23.2	346
BDS @ 50 kilo l ha^{-1} at full dose + RD of NP	7.42	0.42	3.89	148	26.3	310
BDS @ 50 kilo l ha^{-1} at split dose + RD of NP	7.27	0.36	3.66	127	24.2	402
Initial soil	7.24	0.28	3.56	118.5	22.3	228

RD: Recommended dose of fertilizers, BDS:Biomethanated Distillery Spentwash.

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Table 2. Effect of BDS, biocompost and spentwash ash on physiological parameters and nutrient content (%) of multicut fodder sorghum

Treatments	Total chlorophyll (mg/g)	Carotenoid (mg/g)	Reducing sugar (%)	Soluble protein (mg/g)	N	P	K	Na	Ca	Mg	Fe	Cu	Zn	Mn
RD	2.37	0.36	0.59	26.5	1.30	0.24	2.28	0.35	0.54	0.31	254	9.9	19.4	14.2
Biocompost @ 2.5 t ha^{-1} + RD of NP	2.66	0.48	0.68	28.0	1.36	0.33	2.47	0.43	0.64	0.40	263	11.5	23.8	16.8
Spentwash ash @ 400 kg ha^{-1} + RD of NP	2.48	0.40	0.63	26.9	1.32	0.26	2.38	0.38	0.58	0.35	258	10.6	21.2	15.9
BDS @ 37.5 kilo l ha^{-1} at full dose + RD of NP	2.81	0.56	0.73	28.7	1.37	0.31	2.59	0.46	0.68	0.44	268	12.4	25.2	18.0
BDS @ 37.5 kilo l ha^{-1} at split dose + RD of NP	2.52	0.42	0.65	27.2	1.33	0.27	2.44	0.40	0.60	0.37	262	11.0	22.2	16.2
BDS @ 50 kilo l ha^{-1} at full dose + RD of NP	2.72	0.53	0.69	28.3	1.36	0.30	2.52	0.44	0.66	0.42	266	12.0	24.3	17.6
BDS @ 50 kilo l ha^{-1} at split dose + RD of NP	2.56	0.44	0.66	27.5	1.33	0.27	2.41	0.41	0.59	0.38	261	11.2	22.8	16.4
CD (p=0.05)	0.09	0.03	0.04	0.53	0.04	0.02	0.07	0.02	0.03	0.02	3.3	0.44	0.83	0.34

RD: Recommended dose of fertilizers, BDS:Biomethanated Distillery Spentwash

was at par with spentwash ash @ 400 kg ha^{-1} + RD of NP and BDS @ 37.5 kilo litre ha^{-1} at split dose + RD of NP and BDS @ 50 kilo litre ha^{-1} at split dose + RD of NP. This increased nutrients uptake due to more absorption of nutrients by the crop, supplied through nutrient rich BDS and biocompost. These results corroborates with the findings of Suganya (2008). Effluent has a rich source of organics, which may be beneficial to micro-flora besides acting as slow nutrient releaser. Significant improvement was observed in the cations of Ca, Mg, Na and K content by the crop in BDS and biocompost applied treatments. Such improvements were possibly due to the enhanced biomass of the crop thereby increased the uptake of cations. Similar to macro-nutrients, BDS and biocompost had significant influence on the micro-nutrients compared to recommended dose of fertilizer and spentwash ash (Table 2). Among the treatments, BDS @ 37.5 kilo litre ha^{-1} at full dose + RD of NP registered the highest Fe, Cu, Zn and Mn content and the lowest content was recorded by recommended dose of fertilizer. This might be due to that high micro-nutrient content with effluent application (Madhumitadas *et al.,* 2010).

Effect of Distillery Industry Byproducts on Yield

The application of BDS had significant influence in increasing the total green fodder yield when compared to RD and spentwash ash (Table 3). Application of BDS @ 37.5 kilo litre ha^{-1} at full dose + RD of NP (176 t ha^{-1}) recorded the highest green fodder yield, which was at par with BDS @ 50 kilo litre ha^{-1} at full dose + RD of NP (173 t ha^{-1}). Irrespective of the harvests, RD showed the lowest total green fodder yield (157 t ha^{-1}), which was at par with spentwash ash @ 400 kg ha^{-1} + RD of NP (161 t ha^{-1}). The reason might be due to the favourable effect of organic matter and nutrients in distillery wastes, which improved the physical environment and might have promoted better germination, root proliferation, nutrient and water uptake by the crops (Banulekha, 2007).

Effect of Distillery Industry Byproducts on Benefit cost ratio

The treatment, BDS @ 37.5 kilo litre ha^{-1} at full dose + RD of NP recorded the highest benefit-cost ratio and net profit followed by BDS @ 50 kilo litre ha^{-1} at full dose + RD of NP respectively compared to recommended dose of fertilizer (Table 3). The results revealed that the farmers could get a promising economic return in the distillery spentwash wastewater compared recommended dose of fertilizer, where the application of distillery spentwash is free of cost for neighbouring farmers on demand. Hence, basal

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Table 3. Influence of BDS, biocompost and spentwash ash on economics of multicut fodder sorghum

Treatments	Green fodder yield (t ha^{-1})	Total cost (Rs.)	Total return (Rs.)	Net return (Rs.)	BC ratio
RD	157	37131	109900	72769	2.96
Biocompost @ 2.5 t ha^{-1} + RD of NP	170	65097	119000	53903	1.83
Spentwash ash @ 400 kg ha^{-1} + RD of NP	161	39897	112700	72803	2.82
BDS @ 37.5 kilo l ha^{-1} at full dose + RD of NP	176	36796	123200	86404	3.35
BDS @ 37.5 kilo l ha^{-1} at split dose + RD of NP	165	36796	115500	78704	3.14
BDS @ 50 kilo l ha^{-1} at full dose + RD of NP	173	36796	121100	84304	3.29
BDS @ 50 kilo l ha^{-1} at split dose + RD of NP	166	36796	116200	79404	3.16

RD: Recommended dose of fertilizers; BDS:Biomethanated Distillery Spentwash; BC ratio: benefit - cost ratio

application of BDS method could be adopted for better returns.

From the present investigation, it could be concluded that the application of BDS @ 37.5 kilo litre ha^{-1} at full dose + RD of NP increased the nutrient parameters and these are highly correlated with green fodder yield of multicut fodder sorghum. Distillery spentwash from sugar mills hitherto considered as factory waste could be used as a source of nutrients to multicut fodder sorghum. However, the level of application should be within the prescribed limit to avoid development of soil salinity in the long run and it did not affect the ground water quality.

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Adoption Behaviour of Potato Growers in Sub-Tropical Zone of Jammu Division

Quadri Javeed Ahmad Peer*, S.K. Kher, Rajinder Peshin, Nafees Ahmad and Satish Sharma[1]

Division of Agricultural Extension Education
[1]Division of Vegetable Science and Floriculture
Sher-E-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha-180009,INDIA
**E-mail: qadrijavid2008@gmail.com*

Abstract: The study on extent of adoption of recommended irrigation schedule and intercultural practices in potato crop by farmers in sub-tropical zone of Jammu division was conducted during 2011-12. Three districts in the sub-tropical zone of the Jammu division namely Jammu, Kathua and Samba were selected purposively on the basis of maximum area under potato crop. A sample of 225 potato growers was selected from 15 villages. The extent of adoption of recommended irrigation schedule of 5 to 6 irrigations in potato crop was 32 per cent and intercultural practices, that the respondents 32 had adopted recommended irrigation 5-6 numbers and time of irrigation 49 per cent as per recommendation. Similarly, 100 per cent had applied furrow method of irrigation. In case of intercultural practices like hoeing 41per cent and earthing-up 58 per cent of potato growers had adopted these practices. The study further indicated that 16 per cent potato growers had adopted de-haulming practices of potato crop and 68 per cent had adopted manual weed control measures.

Key words: Adoption behaviour, potato, irrigation and intercultural practices, subtropical conditions

Potato (*Solanum tuberosum* L.) is one of the major tuber crop of the world and is also becoming an important source of rural employment and income for growing population (Hort,1987). In India, potato occupies an area of 1786100 hectare with a production of 34400 metric tonnes having mean productivity of 19.4 tonnes/ha (Anonymous, 2008). It is highly remunerative crop particularly in high altitude and cold arid areas of Jammu and Kashmir. In the Jammu division alone, it is a leading cash crop, and has the highest area cover after rice, wheat and maize; sharing 16 per cent in area and 18 per cent in production under vegetables. In the last five years, there has been 10 per cent increase in area from 4845 hectares in 2002-2003 to 5650 hectares in 2008-2009. Similarly the production has shot up by nine per cent during the same period from 75485 to 89600 tonnes, with overall mean productivity of 15.3-16.0 tonnes/ha (Anonymous, 2010). The present study was undertaken to quantify the adoption of important crop practices like irrigation and intercultural practices recommended by the Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu in the subtropical Jammu region.

MATERIAL AND METHODS

Jammu and Kashmir State has varied diverse climatic zones of cold desert, temperate and sub-tropical. The study was conducted in the sub-tropical zone of the Jammu and Kashmir state. Three districts namely Jammu, Kathua and Samba were selected purposively on the basis of maximum area under potato crop. Eleven villages from Jammu district, three villages from Kathua district and one village from Samba district were selected purposively on the basis of proportionality of area under potato cultivation. The villages with the highest area under potato crop in each of the three districts were selected for the present study. Fifteen respondents were selected from each village employing convenience sampling (non-probability sampling) technique where subjects were selected because of their convenient accessibility, thus making a total sample size of 225 from 15 villages (Table1).

The recommendations of irrigation schedule and intercultural practices of Sher-e-Kashir University of Agricultural Sciences and Technology of Jammu (SKUAST-J) were selected for the study. Extent of adoption was measured with respect to percentage of farmers adopting a recommended practice and level of adoption was measured in case of divisible practices namely dosage of pesticides (Singh and Peshin 2000). The interview schedule was administered to collect data. The findings are presented as per the expressed responses of the respondents.

RESULTS AND DISCUSSION

Extent of adoption of irrigation schedule

Sixty-eight per cent of the respondents had applied less than recommended number of irrigations whereas only 32 per cent had given recommended number of irrigations (5-6 times) to potato crop. In Marh sub-division,

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Table1. Sampling plan for selection of the districts, sub-divisions, villages and respondents

District	Sub division	Area under potato crop(ha)[1]	No. of potato growing villages[1]	No. of villages selected by proportionate sampling method (proportionate to area)	No. of potato growers were selected by convenience sampling method
Jammu	Marh	1100	16	7	105
	R S Pura	700	11	4	60
Kathua	Hira Nagar	450	7	3	45
Samba	Samba	85	8	1	15

Table 2. Extent of adoption of irrigation schedule in potato n=225

Irrigation schedule	Sub-division-wise percentage of respondents				Overall %age of respondents from all sub-divisions
	Marh n=105	R S Pura n=60	Hira Nagar n=45	Samba n=15	
Number of irrigation					
As per recommendation	36	28	29	20	32
Not as per recommendation	64	72	71	80	68
Time of irrigation					
As per recommendation	49	50	51	47	49
Not as per recommendation	51	50	49	53	50
Method of irrigation					
Furrow method	100	100	100	100	100

36 per cent of potato growers had applied 5-6 irrigations in potato crop whereas in R S Pura and Hira Nagar sub-divisions 28 and 29 per cent potato growers had applied 5-6 number of irrigations. The difference in the percentage of farmers applying recommended number of irrigations in Marh, R.S.Pura and Hira Nagra sub-divisions was not significant. However, there was significant difference in the percentage of potato growers applying recommended number of irrigations in Marh (36%) and Samba (20%) sub-divisions ($Z= 2.146$, $p=0.031$). Majority of the respondents in all the sub-divisions had applied less than recommended number of irrigations, and almost half of the respondents had not followed recommended time of irrigation to the potato crop. The above findings are in conformity with those of Hakim (1998), Shivalingaiah and Nagabhushanam (2004) and Singh *et al.* (2010) who have reported that majority of the farmers apply less than recommended irrigations to their crops and did not follow recommended interval schedule for irrigating their crops.

Regarding time of irrigation, 49 per cent of the sampled potato growers had irrigated the crop at the recommended time, whereas 50 per cent of had not irrigated the crop at the recommended time intervals. All the respondent potato growers (100 %) had followed furrow method of irrigation in potato crop. Therefore, awareness among potato growers of furrow method of irrigation, and compatibility of furrow method was complete.

Extent of adoption of hoeing and earthing-up practices

Hoeing operation is basic crop practice particularly for tuber crops, and should be done twice, at 20-25 days after planting to pulverize soil for adequate aeration and proper growth and development of growing tubers. The data in Table 3 indicates that all the sampled potato growers had done first hoeing but none had done second hoeing for the control of weeds. Forty-one per cent of them had done hoeing as per recommended time, whereas 59 per cent of respondents had deviated from the recommended time of hoeing. Earthing-up operation is compulsory in potato as it provides a support to the plant, covers tubers and enhance their quality and size. All the sampled potato growers (100 %) had adopted earthing-up, and 59 per cent had followed earthing-up at the recommended time, whereas 41 per cent had deviated from the recommended time. All of respondents had applied lesser number of hoeings but less than half of the respondents had applied hoeing at the recommended time. The reason might be that during winter season, weed growth might be less and had not posed a severe problem to the crop and all of the respondents had done only one hoeing. Majority of respondents had applied earthing-up at the recommended time. The findings of the study are not in conformity with the studies of Deka and Mukhopadhyay (2008) who reported that farmers did not go for earthing-up operation in potato crop, and Sharma (2009)

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Table 3. Extent of adoption of hoeing and earthing up practices in potato (n=225)

Particulars	Sub-division-wise percentage of respondents				Overall %age of respondents from all sub-divisions
	Marh n=105	R S Pura n=60	Hira Nagar n=45	Samba n=15	
Number of recommended hoeing (2 number)					
1st Hoeing	100	100	100	100	100
2nd hoeing	0	0	0	0	0
Time of first recommended hoeing (20-25 days after planting)					
At recommended time	40	37	49	47	41
Not at recommended time	60	63	51	53	59
Earthing-up	100	100	100	100	100
At recommended time (30-35 days after sowing)	60	63	51	53	59
Not at recommended time	40	37	49	47	41

Table 4: Extent of adoption of weed control measures and de-haulming practice in potato crop (n=225)

Particulars	Sub-division-wise percentage of respondents				Overall %age of respondents from all sub-divisions
	Marh n=105	R S Pura n=60	Hira Nagar n=45	Samba n=15	
Manual weed control only	53	73	82	100	68
Both chemical and manual weed control	47	27	18	00	32
Dehaulming	20	17	11	00	16

reported that only 51 per cent respondents went for recommended number of hoeing in potato crop .

Extent of adoption of weed control measures and de-haulming practices

Weeds check growth of the young plant by devoiding it from soil moisture and nutrients. They are detrimental to all crops and should be controlled initially to avoid weed-crop competition. The extent of adoption of herbicide use for weed control was 32 per cent (Table 4). However, these 32 percent potato growers had also done manual weed control. In Marh sub-division higher percentage of potato growers (47%) had applied herbicides. This is for the fact that Marh is vegetable growing belt, and the pesticide use is high in this area (Sharma,2011). The difference in proportion of potato growers applying herbicide was not significant between Marh, R.S. Pura and Hira Nagar sub-divisions. However the difference between Marh and Samba (Z=3.322, p=0.00), R.S. Pura and Samba (Z=3.247, p=0.001), and Hira Nagar and Samba (Z=2.927, p=.003) sub-divisions was statistically significant. Sixty-eight per cent of the sampled potato growers had not applied any herbicide (Table 4). Majority of the respondents had controlled weeds manually. The potato growers had done only one late weeding. The probable reason for delay in weeding might be because of closer planting, less irrigation and low dose of manures and fertilizers. The results in consonance with Hakim (1998) and Badodiya *et al.* (2009) who had reported that majority of the potato growers do one one weeding in potato crop.

Regarding dehaulming, it is a practice of cutting and removal of entire vegetative plant parts, leaving tubers in the soil during aphid free period i.e., in the month of December to avoid viral transmittance in the tubers through vegetative plant plants. A perusal of data presented also in the Table 4, reveals that only 16 per cent of the respondents had done de-haulming practice in potato crop. None of the respondents from Samba subdivision had adopted this recommended practice. Only 16 percent of the respondents had done de-haulming of potato crop because of the reason that they grow the crop for table purposes and not for seed, where virus could spread among the tubers.

Adoption of recommended irrigation schedule was low but the adoption of hoeing for managing weeds was high in the study area. Majority of respondents had applied earthing-up at the recommended time. The use of herbicides for managing weeds was also on the lower side and manual weed management is widely adopted.

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Productivity of Freshwater Carps in Inland Salt Affected Waterlogged Areas of Punjab, India – A Field Study

Meera D. Ansal*, Asha Dhawan and Gurmeet Singh

Department of Aquaculture, College of Fisheries
Guru Angad Dev Veterinary and Animal Sciences University (GADVASU)
Ludhiana, Punjab- 141 004, India
**E-mail: ansalmd@gmail.com*

Abstract: Outdoor research trials were conducted to assess productivity of freshwater carps viz. *Catla catla* Ham. (catla), *Labeo rohita* Ham.(rohu), *Cirrhinus mrigala* Ham. (mrigal), *Cyprinus carpio* Linn. (common carp) and *Ctenopharyngodon idella* Val. (grass carp) at different stocking densities in a semi-intensive poly-culture system in inland salt affected waterlogged waste lands in south west Punjab. Based on preliminary bioassay studies and on-farm rearing of freshwater carps in inland saline water, fingerlings of carps were stocked in earthen ponds @ 10,000 ha^{-1}, 12,500 ha^{-1} and 15,000 ha^{-1}. Fish was fed with farm made supplementary diet @ 5% for the first month and @ 2% during following months. Overall survival of fish remained unaffected and productivity of fish increased from 2.48 tonne (t) $ha^{-1}yr^{-1}$ to 3.40 t $ha^{-1}yr^{-1}$ with increase in stocking density from 10,000 to 15,000 fingerlings ha^{-1}. The studies conclude that owing to reduced growth rate of fish in inland saline water pond as compared to freshwater ponds, the pond accommodated increased stocking density and resulted in 37.5% higher productivity.

Key words: Inland saline water, water logging, carps, survival, growth, productivity

Over the last 3 decades, rising water table and salinization of soil in arid and semi-arid canal irrigated areas of north India is a matter of great concern for the scientists as it has converted a large area of fertile lands into non-productive waste lands. In India nearly 9.38 million hectare (ha) area is occupied by salt affected soils, out of which 5.5 million ha are saline soils (including coastal areas) and 3.88 million ha are alkaline soils (IAB, 2000). In the Indus-Ganga plains of North-Western India, salt affected soils are found in the states of Rajasthan, Gujarat, Haryana, Uttar Pradesh and Punjab (Jain *et al.*, 2002).

Out of the total 5.0 million ha geographical area of Punjab, ground water quality varies from good (59%) to marginal (22%) and poor (19%). The poor waters have been further found to be saline (22%), sodic (54%) and saline-sodic (24%) (Source: Central Soil Salinity Research Institute, Karnal). South-west districts of Punjab, comprising Mukatsar, Ferozepur, Faridkot, Fazilka, Bathinda and Mansa are affected by problem of underground salinity and water logging due to rising water table. Due to non extraction of underground saline water, canal irrigation and inadequate drainage, the water table is rising at an alarming rate (@ 15-20 cm $annum^{-1}$) in southwest districts of the State (Shakya and Singh, 2010). Underground and surface water in these areas is saline and hence is neither fit for agriculture nor for industrial use or human consumption. In such inland salt affected waterlogged areas, where agriculture has very less or no scope, aquaculture is the most suitable option. Although notable efforts have been made in the past to reclaim and utilize these lands through aquaculture, not much could be done in transferring the technologies to the farmers for commercial adoption. This can be attributed to the fact that so far attention was given to assess the possibility of culturing brackish water species (mullets, pearl spot, milk fish, sea bass, tiger prawn etc.) in inland saline waters (Jain, 2007; Pathak *et al.* 2013). Although, these species hold great potential for aquaculture development in inland saline waters, but it holds little commercial application due to non-availability of required quantity of seed. Seed of majority of these species is still collected from the natural resources, which is inadequate to meet the seed demand for commercial aquaculture. Since, freshwater aquaculture sector in India is predominantly freshwater carp culture based and seed of these fishes is also locally available, an outdoor study (based on preliminary bioassay studies) was conducted to work out productivity of fresh water carps (under semi-intensive poly-culture conditions) in inland saline waters, with an objective to assess growth and optimum stocking density of freshwater carps in inland saline waters.

MATERIAL AND METHODS

Preliminary bioassay studies: Indoor bioassay studies were conducted to assess survival and possibility of culturing freshwater carps in inland saline water. Water was lifted from selected salt affected waterlogged areas and preliminary 96-h indoor bioassays studies were conducted (in triplicate) in glass aquaria (100 L capacity) with

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freshwater carps viz; *Catla catla* Ham. (catla), *Labeo rohita* Ham. (rohu), *Cirrhinus mrigala* Ham. (mrigal), *Cyprinus carpio* Linn. (common carp) and *Ctenopharyngodon idella* Val. (grass carp). Different concentrations of saline water, with respect to salinity (0- 15 ppt), were prepared by dilution with fresh water (control). Pre-conditioned fish fry of different sizes i.e., < 5.0 cm (3.5 – 4.3 cm) and > 5.0 cm (5.6 – 6.2 cm), were stocked separately @ 10 per aquarium and kept under aerated conditions throughout the bioassay period. Survival of fish was recorded every 24 hours and dead fish were removed with the help of hand net after every observation.

Preliminary On-farm trial: An outdoor preliminary study (based on bioassay studies) was conducted to work out productivity of fresh water carps (under semi-intensive poly-culture conditions) in inland saline waters. Two ponds (720 m^2) were excavated in inland salt affected water logged areas in village Shajrana of district Fazilka, having an underground water salinity of 15 ppt. Canal water was used as a fresh water source to dilute the underground seepage water to maintain the salinity below 10 ppt. Indian major carps (catla, rohu and mrigal) and exotic carps (common carp and grass carp) were stocked @ 10,000 fingerlings ha^{-1} (recommended stocking density for rearing carps in fresh water ponds) in well fertilized ponds (manured with cow dung - pre-stocking dose @ 1,250 kg $acre^{-1}$) and reared for a period of one year. Fish were fed with farm made feed (rice bran and mustard meal 1:1) @ 5% fish body weight (FBW) daily for the first month and @ 2% of FBW for the following months. Ponds were regularly manured with cow dung at a post stocking dose of 150 kg $acre^{-1}$ every fortnight for sustainable plankton production. Evaporation and seepage loss (especially during dry summer spell) was compensated by adding canal water as and when required, to maintain water level between 5-6 feet and water salinity below 10 ppt. Water quality with respect to pH, dissolved oxygen (D.O.), conductivity and salinity was recorded at fortnight intervals, while growth of fish was observed at monthly intervals. Survival of fish was assessed after complete harvesting of fish at the termination of the experiment.

Fish productivity at different stocking density: Based on the preliminary on-farm trial, further outdoor carp poly-culture research trials were conducted (in duplicate) in salt affected waterlogged waste land in village Shajrana (District Fazilka), to assess the possibility of enhancing productivity of freshwater carps through stocking density manipulations. Raised ponds (680m^2) of 7 feet depth were constructed during the dry summer months by partial digging up to 3 feet and raising the dykes with the help of dug out soil. Ponds got filled up with upward seepage of underground water due to higher water table. Salinity of seepage water was 15 ppt. Canal water was added to raise the water level in the pond to 6 feet and maintaining the salinity below 8 ppt. The ponds were manured with cow dung @ 12,500 kg $ha^{-1}yr^{-1}$ (900 kg $pond^{-1}$). $1/4^{th}$ of the dose (225 kg) was added 20 days before stocking of fish and rest in equal monthly installments of 56 kg each, after stocking fish.

Fish fingerlings were stocked at 3 stocking densities viz. 10,000 ha^{-1} (Treatment-T-1), 12,500 ha^{-1} (Treatment-T-2) and 15,000 ha^{-1} (Treatment-T-3). Surface (catla), column (rohu and grass carp) and bottom (mrigal and common carp) feeding carps were stocked in the ratio of 3: 4:3 and reared for a period of one year. Treatment T-1 served as control, where fish was stocked as per recommendations for stocking carps in a fresh water pond. Fish were fed with farm made feed (rice bran and mustard meal in the ratio of 1:1) @ 5% of FBW daily for the first month and @ 2% for the following months. Feed was applied in the form of dough every day after sunrise at a fixed time and place. Canal water was used to compensate for evaporation loss and seepage loss, if any, to maintain salinity levels below 8 ppt. Water quality analysis was carried out at fortnight intervals with respect to conductivity, pH, dissolved oxygen (D.O.), total alkalinity (TA), total hardness (TH), chlorides (Cl^-), calcium (Ca^{++}), magnesium (Mg^{++}), and sulphate (SO_4^{2-}) concentration, following method of APHA (1991). Salinity of water was tested by using ATAGO-Hand Refractometer, while sodium (Na^+) (K^+) and potassium were estimated with flame photometer. Fish sampling was carried out at monthly intervals to record net weight gain of each species (n=10) and amount of supplementary feed was adjusted accordingly. Nylon threads and reflecting tape were tied over the experimental ponds for protection against predation by fish eating birds like cormorants and herons inhabiting the surrounding waterlogged area.

At the end of the rearing period, whole fish was harvested by draining out the pond completely with the help of a water pump to assess survival (species wise) and productivity of fish in all the treatments. Net weight gain (NWG), specific growth rate (SGR) of fish and feed conversion ratio (FCR) were calculated by following standard methods.

The data was analyzed with a Statgraphic statistical package (Statgraphics version 2.6). One way ANOVA and Duncan's multiple range tests was applied to work out the effect of different stocking densities on growth of different fish species and to determine differences among the treatments ($P \leq 0.05$).

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RESULTS AND DISCUSSION

Preliminary bioassay studies: Bioassay studies revealed that survival of fresh water carps in inland saline waters varied with species and it increased with increase in size of fish. Among the different species, common crap appeared most tolerant followed by rohu and catla, grass carp and mrigal. 100% survival of catla, rohu, mrigal, and grass carp fry of < 5cm size was recorded up to 5 ppt, while common carp fry of < 5.0 cm size recorded 100% survival up to 10 ppt salinity. However, fish fry of > 5 cm size recorded 100% survival up to 8 ppt for catla, mrigal and grass carp, 10 ppt for rohu and 12 ppt for common crap.

Preliminary On-farm trial: Salinity of water varied between 6-10 ppt during the culture period of one year. Fish recorded an overall survival of 85.71% with an average productivity of 2.5 tonnes (t) $ha^{-1}yr^{-1}$, which, indicated scope of freshwater carp culture in inland salt affected waterlogged waste lands, but the productivity was less than the average productivity (6.04 t $ha^{-1}yr^{-1}$) of carps from fresh water ponds in the State (Source: State Fisheries Department). Declined growth of fresh water carps in inland saline water indicated underutilization of carrying capacity of the pond with respect to fish biomass. Chughtai and Mahmood (2012) also recorded 32.5% less yield of freshwater carps (catla, rohu, mrigal, grass carp and silver carp) in inland saline water as compared to freshwater ponds in Pakistan. Based on this finding, further trials were conducted to assess the possibility of enhancing productivity of fresh water carps in inland saline water, by better utilization of pond carrying capacity through stocking density enhancement.

Fish productivity at different stocking density

Water quality: The salinity of water in T-1, T-2 and T-3 treatments varied from 3-8, 3-7 and 3.5 -7 ppt, respectively during the culture period of one year (Table 1, Fig. 1). Salinity of water declined after rainfall and after addition of canal water in the pond. Water quality parameters (conductivity, pH, D.O, TA, TH, Cl^-, Ca^{++}, Mg^{++}, Na^+, K^+ and SO_4^{2-}) in the

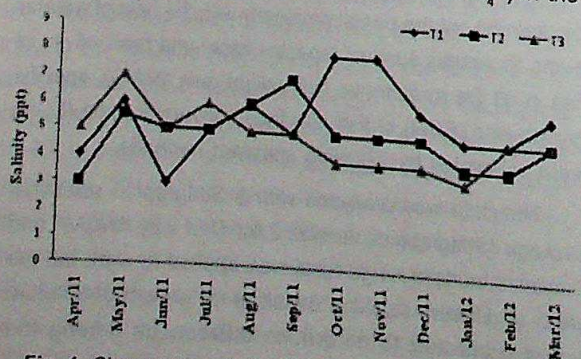


Fig. 1. Changes in salinity of water in different treatments during different months of culture period

Table 1. Range of different water quality parameters in different treatments during the culture period

Stocking density (Treatment)	Salinity (ppt)	Conductivity ($mS\ cm^{-1}$)	pH	D.O. ($mg\ l^{-1}$)	TA ($CaCO_3\ mg\ l^{-1}$)	TH ($CaCO_3\ mg\ l^{-1}$)	Ca^{++} ($mg\ l^{-1}$)	Mg^{++} ($mg\ l^{-1}$)	Na^+ ($mg\ l^{-1}$)	K^+ ($mg\ l^{-1}$)	Cl ($mg\ l^{-1}$)	SO_4^{2-} ($mg\ l^{-1}$)
10,000 ha^{-1}(T-1)	3.0-8.0	4.87- 10.42	7.91-8.30	5.2-5.8	108-130	1180-2200	235-460	144-255	870-1570	370-510	1059-2378	86-177
12,500 ha^{-1}(T-2)	3.0-7.0	4.08-9.47	7.71-8.54	5.8-6.2	104-114	1230-2146	189-358	184-304	860-1370	340-480	1024-1809	81-142
15,000 ha^{-1} (T-3)	3.5-7.0	5.16-9.66	7.81-8.23	5.4-6.2	138-166	1192-2170	198-366	169-305	810-1396	380-460	924-1828	102-146

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different treatments during the experiment are presented in Table 1.

Survival and growth of fish: Survival of different fish species in different treatments is presented in Table 2. Stocking density enhancement from 10,000 to 15,000 fingerlings ha^{-1} appeared to have no affect on the overall survival of fish, which was 82.76%, 74.67% and 90.28% in treatment T-1, T-2 and T-3, respectively.

In treatments T-1 and T-2, mrigal recorded maximum final BW followed by rohu, grass carp, catla and common carp, while in Treatment T-3, mrigal recorded maximum body weight followed by grass carp, rohu, catla and common carp (Table 2) and the differences between different treatments were significant for all the species except catla. Among all the species, rohu recorded maximum SGR, followed by mrigal, catla, grass carp and common crap in T-1 and T-2 treatments, while in treatment T-3, mrigal recorded maximum SGR followed by rohu, catla, grass carp and common carp. In spite of maximum tolerance to inland saline waters, common carp recorded minimum NWG in all the treatments as compared to other carp species.

On average, 169.1, 200.4 and 230.9 kg of fish was harvested from T-1, T-2 and T-3 with an apparent FCR of 2.14, 2.25, and 2.19 (w.r.t supplementary feed only) and an

Table 2. Survival and growth of fish in different treatments

Parameter	T_1 Stocking density-10,000 fingerlings ha^{-1} (Control)	T_2 Stocking density-12,500 fingerlings ha^{-1}	T_3 Stocking density-15,000 fingerlings ha^{-1}
Fish biomassharvested (Kg)	169.10	200.40	230.90
Anticipated productivity (t ha^{-1} yr^{-1})	2.48	2.94	3.40
FCR[1]	2.14	2.25	2.19
Catla			
% Survival	85.77	71.66	96.66
Initial BW (g)[2]	10.10±0.48[a]	9.10±0.69[a]	9.20±0.41[a]
Final BW (g)[2]	203.5±3.41[a]	196.70±9.84[a]	222.3±11.82[a]
NWG (g)	193.4	187.6	213.1
SGR (% BW d^{-1})	0.35	0.36	0.37
Rohu			
% Survival	90.33	94.06	90.25
Initial BW (g)[2]	9.0±0.42[a]	8.10±0.53[a]	8.70±0.39[a]
Final BW (g)[2]	299.0±4.55[a]	318.0±4.99[a]	233.3±16.04[b]
NWG (g)	290	309.9	224.6
SGR (% BW d^{-1})	0.41	0.43	0.39
Mrigal			
% Survival	82.00	86.67	86.00
Initial BW (g)[2]	18.60±0.65[a]	17.30±0.57[a]	18.10±0.58[a]
Final BW (g)[2]	560.0±7.63[a]	482.2±25.79[b]	559.7±15.96[a]
NWG (g)	541.4	464.9	541.6
SGR (% BW d^{-1})	0.40	0.39	0.40
Common Carp			
% Survival	82.40	71.00	78.50
Initial BW (g)[2]	15.2±1.11[a]	16.4±1.07[a]	16.2±1.18[a]
Final BW (g)[2]	135.0±2.06[a]	116.0±3.41[b]	120.3±3.22[b]
NWG (g)	119.8	99.6	104.1
SGR (% BW d^{-1})	0.26	0.23	0.24
Grass Carp			
% Survival	73.33	50.00	100.00
Initial BW (g)[2]	19.60±0.73[a]	19.00±1.12[a]	19.80±0.88[a]
Final BW (g)[2]	259.5±9.99[ab]	240.60±14.02[b]	301.40±10.42[a]
NWG (g)	239.9	221.6	281.6
SGR (% BW d^{-1})	0.30	0.30	0.32

[1] Natural food not taken into account
[2] Values are mean ± S.E. (n=10) and values with different superscript in a row differ significantly (P≤0.5)

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anticipated productivity of 2.48, 2.94 and 3.40 t $ha^{-1}yr^{-1}$, respectively (Table 2). As NWG of all the species was less as compared to that in freshwater, the carrying capacity accommodated increased stocking density, without affecting the survival and growth of fish. Hence, as compared to the recommended stocking density of 10,000 fingerlings ha^{-1}, fresh water carps can be stocked in inland saline waters up to 15,000 fingerlings ha^{-1} for higher productivity.

The results of present study revealed that freshwater carp culture can be taken up in inland salt affected waterlogged waste lands in Punjab. Since, many reports revealing possibility of culture of some brackish water fish species (mullets, pearl spot, milk fish etc.) in saline waters (Barman *et al.*, 2003, Garg, 2003, Jain *et al.*, 2002, 2003, Raizada *et al.* 2003, Jana *et al.* 2004, Jana *et al.*, 2006, Jain, 2007) are available, but it holds little commercial application so far, due to the non-availability of seed on commercial basis. Kumar (2002) reported successful rearing of mrigal in inland saline water of 8-10 ppt salinity at Hisar (Haryana). Singh (2002) harvested 1,068 kg of Indian major carps and 108 kg fresh water prawn (*Macrobrachium rosenbergii*) from one acre inland saline water pond having salinity range of 4.5 -7.0 ppt during the culture period of eight months. Jain *et al.* (2007) were successful in rearing fresh water prawn, *M. rosenbergii* in saline water of 8-10 ppt at Bharatpur (Rajasthan) along with mullet, *Mugil cephalus*. The freshwater prawn attained maximum weight of 125g (average weight 85.8g) in 198 days of culture period. Dhawan *et al.* (2010) also reported an average fresh water carp productivity of 2.5 t $ha^{-1}yr^{-1}$ under poly-culture conditions (catla, rohu, mrigal, grass carp and common carp) from inland saline waters ponds. Chughtai and Mahmood (2012) recorded freshwater carp productivity in the range of 1.19 to 1.41 t $ha^{-1}yr^{-1}$ under poly-culture conditions from inland saline water ponds (EC range 3.38 to 15.1 ds m^{-1}). However, culture of carps in inland saline water of 8-10 ppt at Sultanpur (Haryana) revealed that Indian major carps (catla, rohu and mrigal) could not tolerate this level of salinity, but common carp grew well and attained maturity in less than a year (Anon, 1987). This may be attributed to variations in the ionic composition of inland saline waters in different studies. Salinity and ionic composition of inland saline water from different spots differs even with small distances within an affected area. Further, ionic composition of inland saline water from different areas also differs even at same salinity levels (Dhawan *et al.* 2009). The present study reveals that fresh water carps can be reared in inland salt affected waterlogged areas (salinity up to 8 ppt) of Punjab, at a stocking density of 15,000 fingerlings ha^{-1} with an average productivity of 3.40 t ha^{-1} yr^{1} and an annual net profit of Rs. 1,00,000 to 1,20,000 ha^{-1}. However, there is need to generate database not only with respect to inland saline pockets in the region, but also the ionic composition of water, for generating suitable region specific aquaculture packages.

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Electronic Display Boards (EDBs) for Fisheries Advisory Services in Maharashtra

Suhas Wasave, Lloyd Chrispin, Apu Das, Sandeep Pedapoli, Brijesh Kumar Choudhury and Arpita Sharma*

Central Institute of Fisheries Education
Deemed University, Indian Council of Agricultural Research, Mumbai – 4000 61
**E-mail:arpitasharma@cife.edu.in*

Abstract: Fisheries play an important role in Indian economy. While on the trip to fishing, the fishers mostly rely on the Indigenous Technical Knowledge (ITK) and personal experiences to catch the fishes. Indian National Centre for Ocean Information System (INCOIS), Hyderabad started advisory services like Potential Fishing Zone (PFZ) through the Electronic Display Boards (EDBs) which provides information about probable potential fishing zones prior reaching to the particular ground on the scientific Catch Per Unit Efforts and assured minimum returns to daily investment by the fishers. INCOIS provides advisory services in Maharashtra too. Status of Electronic Display Boards (EDBs) which provide PFZ services and are installed by INCOIS in the fishing villages of Mumbai, Ratnagiri and Sindhudurg districts of Maharashtra was studied and awareness of EDBs, its usefulness amongst the fishers was also studied. It was reported by the fishers that EDBs provide information regarding pelagic fisheries whereas fisher targets for commercially valid crustaceans/fishes (most of them are demersal) leading to non usage of EDBs. In addition to this, the trust in and usage of ITKs in fishing is more than the technological inputs, in giving ensured and profitable catches highlighting the importance of ITKs. Integration of ITKs with modern technological tool is thus suggested.

The fishers mostly rely on the Indigenous Technical Knowledge (ITK) and personal experiences to catch fishes. Some of the ITKs practiced by fishers to detect fish in sea are smell of water, sliminess of water, water current, wind direction, water temperature, presence of birds on the sea surface etc (Sharma *et. al.* 2012). When fishers reach the fishing ground and find few or no fish they face financial loss as they have already spent valuable resources like money on fuel as well as their time and energy which result in upset state of mind. In addition to this, drastic exploitation of pelagic resources by both the mechanized and motorized fleets over the decades within the contiguous zone has brought a hallucination of 'no resource for growth' tag to their marine resources. To mitigate these problems countries like U.S.A and U.S.S.R started satellite based information system to predict the tsunamis, cyclones and weather warning. On the same lines, Government of India started advisory services for Potential Fishing Zone (PFZ), Ocean State Forecast (OSF) which provides information about probable potential fishing zones prior reaching to the particular ground on the scientific bases. Such advisory services have been developed by Indian National Centre for Ocean Information System (INCOIS), Hyderabad which was established in the year 1992 (Annual Report, INCOIS, 1998-99). It has aim to increase the Catch Per Unit Efforts (CPUE) and assured minimum returns to the daily investment by the fishers. The study undertaken by INCOIS on usefulness of PFZ advisory to the fishers noticed that fishing in the PFZ areas showed a significant increase in the revenue generated with the average CPUE recorded from the vessels operating in the PFZ areas was as 33.01 kgh^{-1} and from the non-PFZ locations the CPUE recorded was 30.15 kgh^{-1}. It showed an increase of approximately 15-20% in the revenue when vessels fished in the PFZ areas and this was estimated on the assumption that the skipper has no prior knowledge on the location of the INCOIS derived PFZ (Annual Report, CIFT, 2010 – 11).

The PFZ advisories are generated for the use of artisanal, motorized and small mechanized sector fishers engaged in pelagic fishing activities such as ring seining, gill netting, etc., to help them in reducing the searching time which in turn result in the saving of valuable fuel oil and also human effort (Annual Report, Ministry of Earth Science, 2007 – 08). Narayankumar *et. al.* (2009) reported that the catches in PFZ area gave more CPUE and net profit compared to the results of the operation in non-PFZ. Further they stated that in Kerala, a reduction in searching time to an extent of 60-70% for oil sardines and 30-40% for mackerels was observed after following the PFZ advisories.

The commissioning of satellite OCEANSAT in 1999, which provides the real-time pictures of ocean colour (chlorophyll-A) along with Sea Surface Temperature (SST) has helped the organisation in identifying the Potential Fishing Zone (PFZ), which was one of the main pre-requisites for economical fishing activity (INCOIS, 2012). The PFZ Advisories are reaching to 500 villages / landing centres, covering the entire coast line of India under 12

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sectors, viz. Gujarat, Maharashtra, Karnataka and Goa, Kerala, South Tamil Nadu, North Tamil Nadu, South Andhra Pradesh, North Andhra Pradesh, Orissa and West Bengal, Lakshadweep Islands, Andaman Islands and Nicobar Islands. Total 384 PFZ advisories prepared in the local languages and local measurement units are disseminated thrice a week (on every Monday, Wednesday and Friday) and are supplied by INCOIS during the non-ban, non-monsoon and cloud free period through innovative and novel initiatives such as electronic display boards and information kiosks, Doordarshan, print media, e-mails and through INCOIS website supplemented with fax and telephone to all coastal fishing villages/fish landing centres. There are over 100 000 mechanised fishing vessels, out of which about 60000 are utilising PFZ advisories. In addition to the mechanised boats, there are more than 100000 traditional fishing crafts. (Kumar, 2011).

Among the disseminating system of INCOIS, internet and FAX are serving individual fisher but the Electronic Display Boards (EDBs) are serving many number of fishers at a time. In Maharashtra, four Electronic Display Boards (EDB's) were installed in fishing villages namely, Versova (Greater Mumbai district) Mirkarwada and Harnai-Paj (Ratnagiri district) and Dandi- Malvan (Sindhudurg district). The dissemination of PFZ on these digital display boards was started in February, 2002. The response from fishers was weak until the year 2006 (Bhaware *et al.* 2010). In the present study, status of Electronic Display Boards (EDBs) installed by INCOIS established at Greater Mumbai, Ratnagiri and Sindhudurg districts of Maharashtra was studied in order to assess the awareness of EDBs and its usefulness amongst the fishers. In addition to this, information was also collected as regards to extent of usage of EDBs by the fishers to get the advisory services.

MATERIAL AND METHODS

Information was collected by visiting all the fishing villages i.e., Verosva in Greater Mumbai, Mikarwada and Harnai-Paj, fishing villages in Ratnagiri and Dandi-Malvan, in Sindhudurg where the EDBs are installed. Interview method and observation was used to collect information. The study was conducted in 2012.

RESULTS AND DISCUSSION

Status of Electronic Display Boards (EDB) in Maharashtra

In Mumbai district, EDB is installed at a fishing village Versova on the first floor of *Nakhwa Mandal* (Trawlers Associations) office in association with INCOIS, CIFE, Mumbai and *Nakhwa Mandal*, which is very near to the fish landing centre. At Versova two visits were made in the month of November. However, at the time of visits, the EDB was not working.

At Ratnagiri district, two EDBs are installed, one is in Mirkarwada fishing village and another is in the fishing village Harnai-Paj, Taluka, Dapoli. In Mirkarwada, two visits were made in the month of September and November where it was reported that the EDB installed in collaboration of INCOIS, Dr. Babasaheb Ambedkar Marathwada Vidyapeeth and Department of Fisheries, Maharashtra state. Whereas in Harnai-Paj the EDB was found installed in collaboration with INCOIS, and Department of Fisheries, Maharashtra state. At the time of visit, both the EDBs were found in non working condition.

At Sindhudurg district EDB is installed in the fishing village Dandi-Malvan in collaboration of INCOIS and Department of Fisheries, Maharashtra state. At Sindhudurg, visit was made twice in the month of September and November. However, the EDB was not found to be in working condition.

The information on Status of Electronic Display Boards (EDBs) in Maharashtra is presented in brief in table 1.

Awareness about the usefulness of EDB among the fishers

As regards to the awareness about the presence of EDB in the village among the fishers it was found that in fishing village Versova, Mumbai where EDB is installed at

Table 1. Status of Electronic Display Boards (EDBs) in Maharashtra

Place	Greater Mumbai	Ratnagiri		Sindhudurgh
Fishing village	Versova	Mirkarwada, Harnai-Paj		Malvan
Agency/service Provider	INCOIS, CIFE, *Nakhwa Mandal* (Trawler Association)	INCOIS, Mirkarwada Adarsh Macchimar Sahakari Sanstha Maryadit, Mirkarwada	INCOIS, Harnai-Paj Fishing Trading and Credit Co-operative Society Ltd- Paj-Pandhari	INCOIS, Shree Rameshwar Macchimar Sahakari Society Maryadit, Malvan
Target fishers	Trawlers	Trawlers/ purse – seine	Trawlers/ purse – seine	Trawlers
Year of initiation	2008	2002	2002	2008
Services offered	PFZ	PFZ	PFZ	PFZ

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the *Nakhwa Mandal* (Trawlers Associations) office, members of the *Nakhwa Mandal* were aware about the EDB. But, the fishers who were not members of *Nakhwa Mandal* were not aware of the presence of EDB.

At Ratnagiri district, two EDBs are installed, one is in Mikarwada fishing village and another is in the fishing village Harnai-Paj, where as in Sindhudurg district, the EDB is installed in the fishing village Dandi-Manlvan. Most of the fishers of Mirkarwada and even the nearby fishing villages were found to be aware of the EDB and fishers were frequently using the information when EDB was in working condition. Harnai-Paj and Dandi-Malvan fishers were also aware of the presence of the EDB at their respective villages and they frequently availed the information during its operational condition.

Awareness about the usefulness of EDB among the fishers

In Mumbai district, fishing village Versova it was reported that there was awareness about the usefulness of EDBs by only those fishers who were members of *Nakhwa mandal* and had attended awareness campaigns organized by INCOIS, CIFE and *Nakhwa mandal*.

At Ratnagiri district, it was reported that the College of Fisheries, Ratnagiri conducted special awareness programmes in the village Mirkarwada and Harnai-Paj. The fishers reported that they were very well acquainted with the usefulness of EDB installed at their place.

In Sindhudurg, information about the utility of EDB was provided to the fishers by Department of Fisheries at the time of its installation but there was lack of awareness regarding usefulness of EDBs amongst the fishers.

With reference to the frequency/extent of services offered through the EDBs it was reported by the fishers that initially when the programme started, EDBs were in a working state. But after some time all the three EDBs were non-functioning and unable to provide PFZ advisory services.

It was reported by the fishers of Malvan fishing village that when the EDB was working, only few of the fishers were utilising the information. Further enquiry revealed that most of the fishers were operating gill nets and shore seine (*rampan*) and according to the fishers EDBs were unable to provide suitable information for these operations.

At Ratnagiri, when the EDBs were in working condition, most of the fishers especially purse -seine owners of Mirkarwada fishing village and Harnai-Paj fishing village availed the information. The fishers of Ratnagiri and Harnai-Paj also revealed that the PFZ advisory was providing the information which was 60-70% valid especially in case for purse-seiners. A study by Bhaware *et. al.* (2010) have reported that overall the PFZ advisories were found to be more beneficial to the purse-seine and trawl fisheries than to the gill net fishery for the fishers of Ratnagiri district.

During study, one interesting thing was reported that even the EDBs of Mirkarwada and Harnai-Paj were not supplying information; the fishers of that region were availing PFZ advisory directly through email and internet. It was reported that this was due to the awareness programmes conducted by College of Fisheries, Ratnagiri in which fishers have been explained the importance of PFZ advisory and demonstration has been done for the fishers how to avail the information on email and internet.

It is reported that, INCOIS organises field awareness campaigns at various fishing harbours with active participation of fishers for providing information on PFZ Advisory Service and the benefits of the PFZ to the fishing community (Annual Report, Ministry of Earth Science, 2007–08).

But the fishers of Mirkarwada and Harnai-Paj also attended awareness programme conducted by College of Fisheries, Ratnagiri. With reference to the extent of usage of EDBs by the fishers to get the advisory services, it was reported by fishers of all villages that even when EDBs were in working state, fishers do not rely completely on it. Reasons reported were that EDBs only provides information regarding pelagic fisheries whereas fishers target commercially valid crustaceans/fishes (most of them are demersal). In addition to this, the trust in and usage of ITKs in fishing always outsmarts such technological inputs, in giving ensured and profitable catches highlighting the importance of ITKs.

EDBs can act as effective ICT tool in providing information to fishers. If they are located in common and accessible place majority of fishers can take advantage of it. The study has revealed that the EDBs installed in Maharashtra are not in working condition. It is suggested that working of the EDBs be ensured. Moreover, it is suggested that the services provided be species specific. In case of Versova fishing village, services are not of much use as trawler owners target demersal fish but the PFZ services are for pelagic fishery. The PFZ services in Ratnagiri was used by fishers as majority of fishers have purse-seine and trawl nets hence and PFZ information is very much related to them. At Malvan fishing village the fishers are using gill net fishery and shore siene. The advisory services are useful to a certain extent but to make it more useful the services should be focused on gill netters. The advisory services can be further strengthened with the use of mobile phones as its usage is common among the fishers and

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individual fishers can be targeted in providing them with the required information. This is evident from the success of SMS based advisory services provided by MSSRF in Tamil Nadu and Andhra Pradesh (Chrispin *et al.*, 2012 and Pedapoli, 2012). In addition to this, the trust in and usage of ITKs in fishing is more than the technological inputs, in giving ensured and profitable catches highlighting the importance of ITKs. So it is suggested that the modern technological methods be integrated with the ITKs used by fishers.

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Physicochemical and Microbial Changes in Natural and Planted Mangrove Habitats of Southeast Coast of India

K. Sakthivel and K. Kathiresan

Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai-608 502, Tamil Nadu-India

**E-mail: ksakthi7@yahoo.co.in*

Abstract: Physicochemical and microbial analysis was made in sediments of natural and restored mangroves at Pichavaram, southeast coast of India. The parameters analysed were tidal height, tidal spread, humidity, temperature, pH and pore water salinity of soil, microbial counts and levels of nutrients (N, P, K, total sugars, total amino acids, tannins, total organic carbon) at monthly intervals for one year. In planted mangrove habitats, there was a significant increase of fine soil particles, moisture retention, total organic carbon and nutrients in particular N, P, K, tannins and amino acids, along with increased microbial counts in the sediment soil. The results reiterated that the mangrove planting was beneficial in promoting the fine soil particles, nutrients and microbial colonization of the habitat thereby improving the habitat function.

Key words: Mangroves, microbes, nitrogen; phosphorus, potassium, soil

Mangrove habitats are among the world's most productive ecosystems situated at the interface between land and sea in tropical and subtropical latitudes. Their role in protecting shores from wind, waves and water currents; preventing soil erosion; supporting fisheries and livelihoods are well known (Kathiresan and Bingham, 2001; Kathiresan and Qasim, 2005; Bhatt and Kathiresan, 2011). However, the mangroves disappear globally at a rate of 0.66% per year (Spalding *et al*., 2010). There have been spurred activities in restoration of mangrove forests, but without assessment of recovery in many areas (Bosire *et al*., 2008; Ellison, 2000; Walters *et al*., 2008). The effect of mangrove planting on changes in soil characteristics has not been properly studied. Therefore, the present study was made to compare the natural and restored mangroves for physicochemical and microbial changes in their habitats.

MATERIAL AND METHODS

Three mangrove habitats of southeast coast of India were analysed in three areas along the southeast coast of India: Pichavaram with natural mangrove formation (Lat.11° 27' N; Long. 79° 47' E) and other two artificially developed mangroves by our research team at Parangipettai (Lat. 11° 29' N; Long. 79° 47' E) with 19 year old and at Mudasal Odai (Lat. 11° 28' N and Long. 79°46' E) with 9 years old mangrove forests. All the sites were dominated with mangrove species such as *Rhizophora mucronata* Poir, *R. apiculata* Blume and *Avicennia marina* (Forssk.)Vierh.

The parameters analysed were tidal height, tidal spread, humidity, temperature, pH and pore water salinity of soil, microbial counts and levels of nutrients (N, P, K, total sugars, total amino acids, tannins, total organic carbon) at monthly intervals for one year. The tidal height and spread were recorded by using a measuring tape. Humidity of atmosphere was measured by using a hygrometer (Huger, West Germany). The temperature of sediment was measured in the field using a 0.5°C accuracy centigrade thermometer, by inserting it 5 cm below the soil surface. The pore water salinity was measured using a refractometer (Erma, Japan) in the water soil sample squeezed out from soil samples through a syringe with muslin cloth. The pH of the soil samples was recorded by using a pH cone (Elico, India). Moisture content of the soil was recorded by weighing five grams of soil sample before and after shade-drying. The air-dried soil samples were further analyzed for their texture by sieving method, using a Ro-Tap mechanical sieve shaker. The soil samples were passed through sieves of different mesh sizes such as, 0.5 mm (for course sand), 0.25 mm (for medium sand), 0.125 mm (find sand), 0.063 mm (very fine sand), 0.037 (silt) and bottom tray for the collection of clay. The fraction of soil sample retained from 0.5 to 0.063 mm considered as sand. The soils composition were analyzed by weighed different fraction such as sand, silt and clay and expressed in percentage basis.

Total heterotrophic bacteria were isolated from fresh soil samples, adopting serial plating technique using ZoBell's agar medium following the method of Chandramohan (1988). The samples were diluted to thousand times and used it for inoculation. From this dilution, 1 ml was pipette out into sterile Petri dish and mixed thoroughly with ZoBell's agar medium and allowed

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to solidify. The plates in triplicates were incubated at a room temperature (29 ± 1°C) for 2-4 days and the number of colonies appeared on the medium were counted. The bacterial counts are expressed as colony-forming units (CFU) per gram wet weight of the soil samples.

Total sugar, amino acids and tannins were estimated in the wet soil samples. One gram of the sample was mixed in 10 ml of distilled water. The mixture was centrifuged at 3000 rpm for minutes. The supernatant was made up to the final volume of 10 ml with distilled water and analyzed for total amino acids (Moore and Stein, 1948), total sugar (Dubois *et al*., 1956) and total tannins (Hagerman and Butler, 1978). The values are expressed as milligram per gram of the soil. Organic carbon in soil sample was estimated by following the method of El Wakeel and Riley (1956). The procedure involved chromic acid digestion and subsequent titration with ferrous ammonium sulphate solution in the presence of 1, 10 phenonthroline indicators. The values calculated are expressed in milligram per gram of soil sample. Soil nitrogen was estimated by using Kjeldhal method (Jackson, 1971). The soil was digested with conc. H_2SO_4 at temperature 360-400°C. The digested samples were then transferred to distillation unit tipped into the boric acid. The unit was heated initially at a low temperature and then increased the heat gradually. The distillate was collected in the boric acid and titrated with standard 0.1 N H_2SO_4. The total nitrogen concentrations calculated and expressed in milligram per gram of soil. Phosphorus of soil was estimated by following the method described by Atkinson (1987). In this method, total phosphorus was extracted from known amount of samples in hydrochloric acid. The residue was reconstituted with triple distilled water and then digested with potassium persulphate. The organically bound phosphorus present in soil samples was converted to reactive phosphate. The values are expressed as milligrams per gram of the soil.

RESULTS AND DISCUSSION

The soil temperature ranged from 26.4 to 33.5°C and the fluctuation of temperature was almost similar in three sampling sites, because of the closeness of the sites which are located within seven square kilometer distance. There are two distinct seasons in the study area: summer (May-July) and winter (October-December). According to the atmospheric temperature, the soil temperature varied seasonally: it was low during winter months and gradually increased up to summer months, then reduced thereafter. The soil salinity ranged between 4.6 - 37.8 ‰, its depending on rainfall. High rainfall during winter months recorded the lowest salinity and increased thereafter during summer months in all sampling sites. The soil pH also showed the same trend and it ranged from 7.7 to 8.5. The humidity ranged from 79 to 95% and it was high during winter months and low in summer months, almost similar in all sampling sites. Tidal spread and height of sampling sites depend on topography and river mouth opening of the sampling sites. Pichavaram exhibited lower tidal height than other two sites. The mouth opening is very close in Parangipettai and Mudasal Odai and hence these sites exhibited the highest tidal height particularly in winter months. The tidal spread was maximum in Parangipettai followed by Mudasal Odai and it was minimum in Pichavaram (Fig. 1).

In Pichavaram, sampling sites had highest percentage of soil moisture (23.83) during summer months compared to other restored mangrove sites. In general, soil composition had highest percentage of sand (87.7) followed by silt (10.87) and clay (1.39). The sand percentage ranged from 79.8 in Pichavaram on July to 94.9 in Mudasal Odai on March. In all sampling sites, during winter months and after summer months recorded low percentage of sand . The silt ranged from 3.43 per cent in Parangipettai on February to 16.8 per cent in Pichavaram during September. It showed two peaks during winter as well as summer months. The level of soil nutrients was found dependent on the content of silt and clay. The highest percentage of clay (3.4) was recorded in Pichavaram sampling site on July. The percentage of clay gradually increased from winter months to summer months then again decreased in all sampling sites (Fig. 2).

The total heterotrophic bacterial count was high ($982x10^3$) in soil samples of Pichavaram than the other restored sampling sites: ($651x10^3$) at Parangipettai and Mudasal Odai ($830x10^3$). During summer months particularly on April, the bacterial count ($443x10^3$) was reported low in all sampling sites, while the count was high during winter and post-winter period. This trend coincided with the levels of total sugars, amino acids and tannins in the soil samples. The level of soil sugar (0.76 mg/g) was highest at Pichavaram during winter on November and lowest in Mudasal Odai during summer on June. In general, summer months recorded low level of soil sugar in almost all sampling sites. The level of total amino acids showed a general peak during winter and pre-winter and lowest levels in mid-summer months. For example, the levels exhibited peaks (18.8, 11.7 and 13.8 mg/g) on December, February and July in Pichavaram while the other two sampling sites, the range of total amino acids was more or less similar in all seasons. Level of tannin in soil was the lowest (1.05 mg/g) on April in Parangipettai, while it was highest (6.64 mg/g) on December in Pichavaram. During post winter

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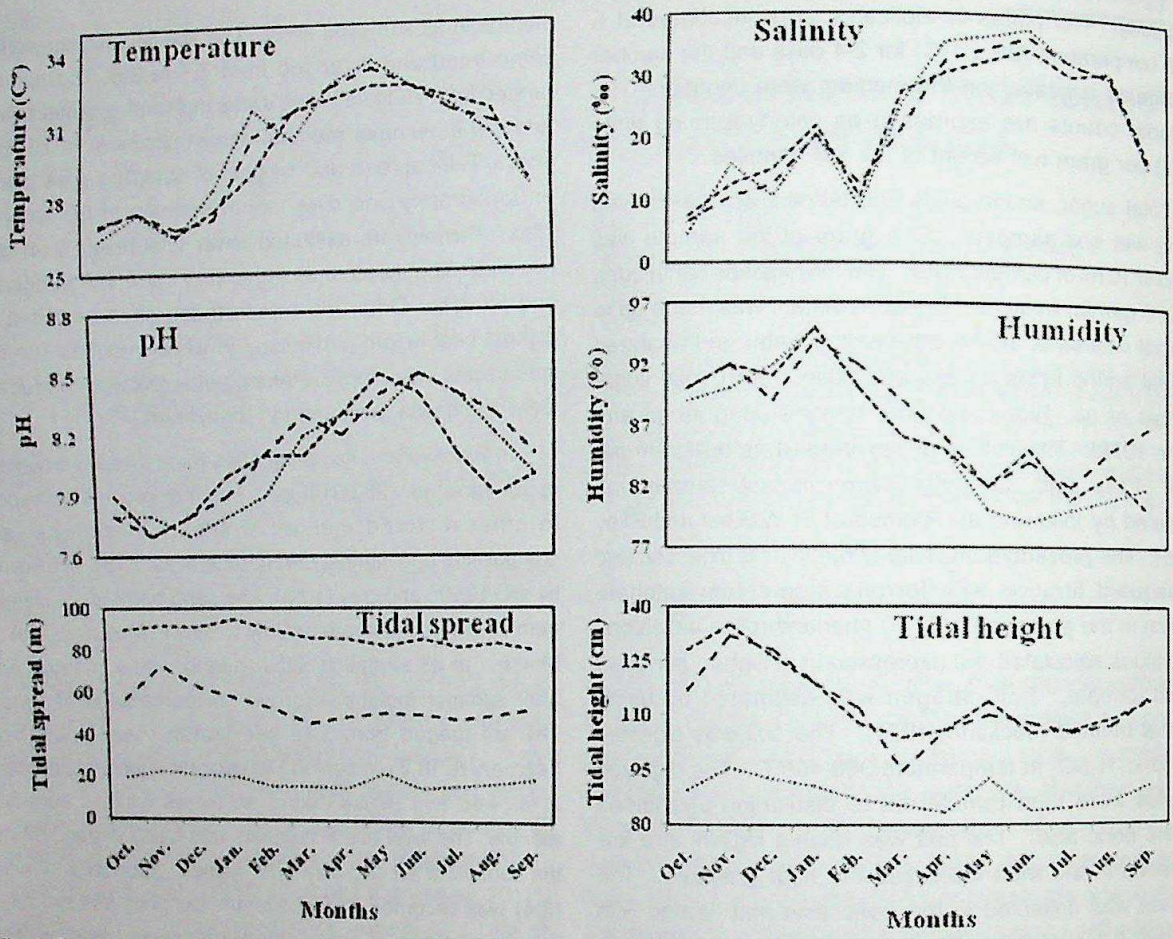


Fig. 1. Temperature, Salinity, pH, Humidity, Tidal spread and Tidal height (cm) in three mangrove habitats (..... Pichavaram; ——— Parangipettai; - - - - - Mudasal Odai) at monthly interval for one year.

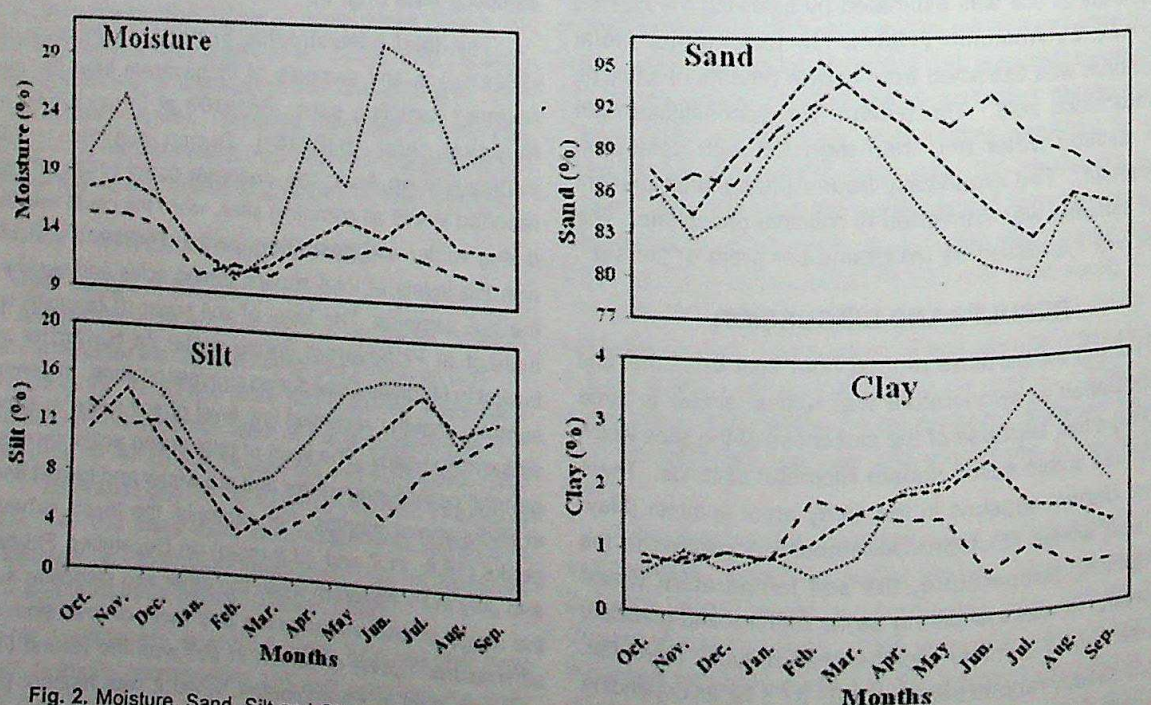


Fig. 2. Moisture, Sand, Silt and Clay in soil samples drawn from three mangrove habitats (..... Pichavaram; ——— Parangipettai; - - - - - Mudasal Odai) at monthly interval for one year.

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and summer (January to June) only low level of tannins was recorded in all sampling sites (Fig. 3).

Total Organic Carbon (TOC) gradually increased from winter to summer months. The highest peak of TOC (13.3 mg/g) on August and lowest TOC (0.87 mg/g) on November were reported in Pichavaram sampling site. The lowest nitrogen (0.33 mg/g) on December in Mudasal Odai and highest nitrogen (1.26 mg/g) on June in Pichavaram were recorded. Generally the nitrogen level was low on winter months, and then increased on summer months in all sampling sites. A similar trend was noticed for the level of soil phosphorus. The highest phosphorus peak (0.95 mg/g) was reported on May in Pichavaram while it was (0.72 mg/g) at peak in the same month in Parangipettai. Level of potassium was recorded low during winter months in all sampling sites and high during summer months. The minimum level of potassium (0.14 mg/g) was recorded on November in Parangipettai, while maximum was recorded on April in Pichavaram (0.62% mg/g) and in Mudasal Odai (0.31 mg/g) on June (Fig. 3).

The soil salinity ranged from 4.6 - 37.8 ppt with the mean value of 22.62 ppt during the present study. Maximum soil salinity was reported on summer months in all sampling sites (Fig. 1 & Table 1). The ultimate source of salinity in the study areas is the neritic water, ingression of which is higher during summer than during winter. The high temperature in summer also increases evaporation resulting in high salinity (Kathiresan, 2000). According to Naidoo and Raiman (1982), soil salinity is related to the extent of tidal inundation and seepage in the mangrove soils of Sipingo and Mgeni, South Africa. In the present study, all sites are regularly inundated by diurnal tides and fresh water flow and hence low salinity was recorded during winter (Fig. 1). The soil pH during the present study was alkaline with mean value 8.08 with a range from 7.7 to 8.5 in all sampling sites (Fig. 1 & Table 1) and the result is in accordance with Pal *et al.* (1996) on the mangrove soils of the Sundarbans. Tidal influence is also not a requirement, but playing an important indirect role. Inundation with saltwater helps to exclude most other vascular plants and reduces competitions. Tides bring saltwater upper estuaries against the outflow of freshwater and extend mangrove development inland. Tides transport sediments, nutrients and clean water into the mangrove environment and export organic carbon and reduce sulphur compounds. The present study recorded the tidal spread which ranged from 15 – 95 m with mean value 34 m while the tidal height ranged from 83.4 – 135 cm (Fig. 1). The tidal spreading area is lesser in Pichavaram than the other sampling sites, because of the high elevation of intertidal area. Similarly tidal height is also very less in Pichavaram than the other sampling sites, because of the river mouth opening which is away from the site.

The soil nitrogen ranged from 0.33 – 1.26 (mg/g) with mean values of 0.63 (mg/g). It was higher in natural mangroves (0.83 mg/g) than that in planted mangroves: Parangipettai (0.60 mg/g) and Mudasal Odai (0.47 mg/g) during the present study (Fig. 3 & Table 1). This high level of nitrogen can be attributed to riverine input or bacterial activity. Nitrogen fixing bacteria are known to increase nitrogen in mangrove soil (Kathiresan, 2002). These microorganisms incorporate nitrogen from the atmosphere and convert nitrogen present in the soil into ammonia, which makes nitrogen available for its use by the plants (Kathiresan, 2000). The mean value of phosphorus was 0.47 mg/g with a range of 0.21 – 0.95 mg/g. It was higher in natural mangroves (0.64 mg/g) than in planted mangroves-Parangipettai (0.44 mg/g) and Mudasal Odai (0.33 mg/g) (Fig. 3g & Table 1). In the present study the mean value of potassium 0.36 mg/g ranging from 0.17 to 0.62. It was higher in Pichavaram (0.47 mg/g) than in Parangipettai (0.27 mg/g) and Mudasal Odai (0.34 mg/g) (Fig. 3h & Table 2). The mangroves exhibit better growth performance in the sites enriched with potassium, as experimentally proved earlier in our laboratory (Kathiresan *et al.*, 1994) and this growth performance is indirectly associated with the beneficial microbes present in the soil adjacent to the mangrove roots (Kathiresan, 2000).

In the present study the mean value of total organic carbon (3.66 mg/g) with range from 0.87 – 8.68 mg/g was recorded. It was higher in natural mangroves (3.85 mg/g) than planted mangroves: Parangipettai (3.53 mg/g) and Mudasal Odai (3.59 mg/g) (Fig. 3 & Table 1). The major source of organic carbon is the plant and animal matter which are transported from land through river run-off and settled from the overlying water of mangrove habitats. In the present study the minimum percentage soil clay (0.85%) and Total Organic Carbon (1.65 mg/g) were recorded during winter season (Fig. 2 & 3). This indicates that finer soil particles along with organic fractions would have washed away by the freshwater flow. The maximum level of nutrients during summer months in the study areas is due to nutrient regeneration from fallen leaves, twigs, buds, flowers, decaying roots, etc (Reyes and Fortes, 1985). Heterotrophic bacteria are very important in mangrove habitats as the bacteria decompose the mangrove litter, recycle the nutrients and produce the detritus food for many fishes (Rajendran and Kathiresan, 2007). The present study the mean value of total heterotrophic bacteria was 611 x 10^3 with a range of 357 to 982 x 10^3. It was higher in natural mangroves (759.5 x 10^3) than that in planted mangrove

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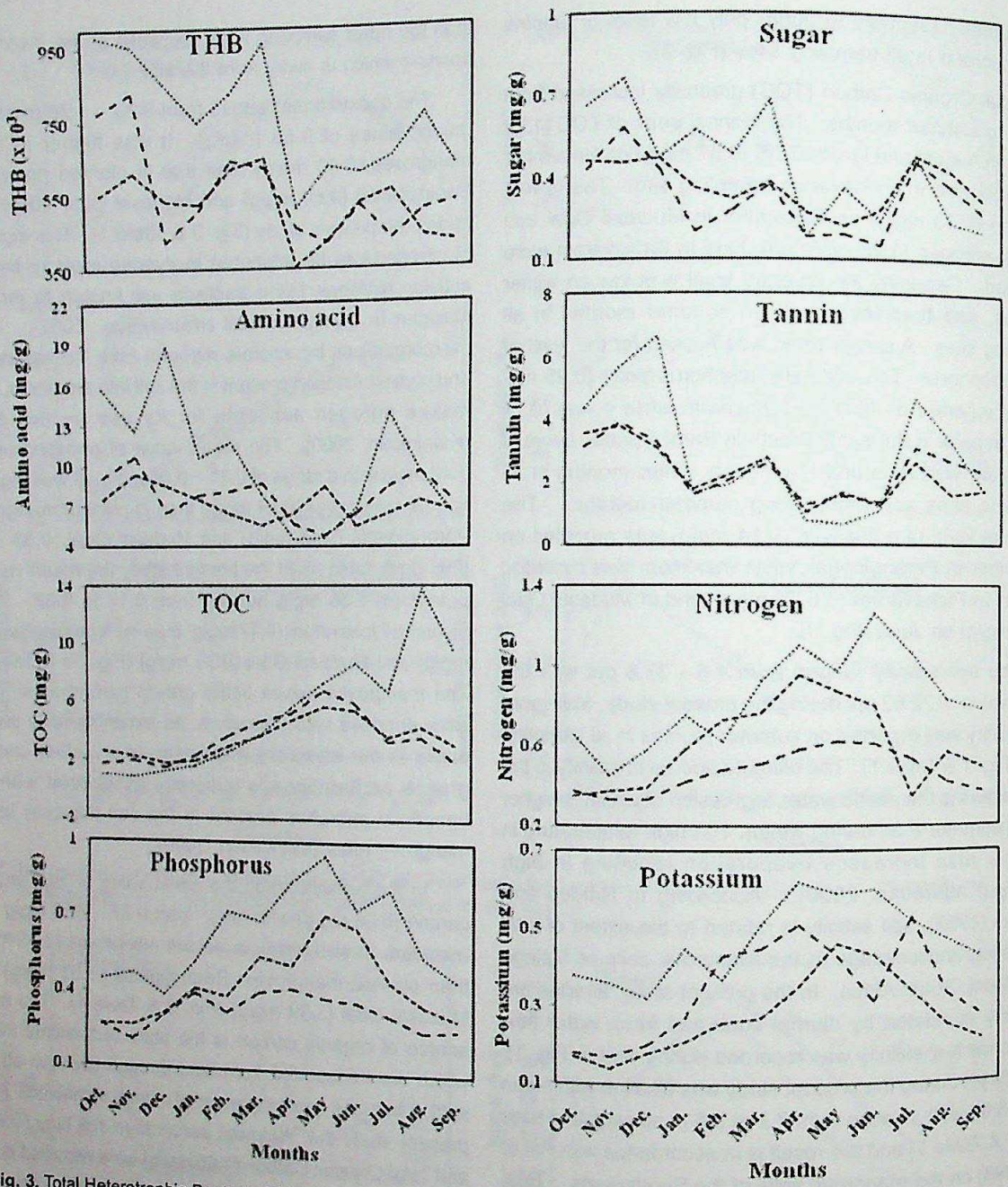


Fig. 3. Total Heterotrophic Bacteria (THB), Sugar, Amino acid, Tannin, Total Organic Carbon (TOC), Nitrogen, Phosphorus and Potassium in soil samples collected from three mangrove habitats (..... Pichavaram; ——— Parangipettai; - - - - - Mudasal Odai) at monthly interval for one year.

areas - Parangipettai (518.92 x 10^3) and Mudasal Odai (556.2 x 10^3) (Fig. 3 & Table 1). Infact, pristine mangroves are known to colonize much higher counts of total heterotrophic bacteria as compared to degrading mangroves (Kathiresan, 2002).

Planted mangroves (Parangipettai and Mudasal odai) exhibited higher levels of sand and low levels of clay and silts than the natural mangroves (Pichavaram) (Fig. 2a-d). In the planted mangroves, 19 year old mangroves (Parangipettai) showed higher levels of clay and silts and lower level of sand than 9 year old mangroves (Mudasal odai). Thus the plantation appeared to change the soil composition with more fine particles through siltation process. The high level of soil fine particles also was evident by high level of soil moisture and levels of nutrients. The natural mangrove habitat exhibited high levels of nitrogen, phosphorus, potassium, total organic carbon, amino acids and tannins, as compared to planted mangrove sites. In

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Table 1. Average values of physicochemical parameters analyzed from natural (Pichavaram) and planted (Parangipettai and Mudasal odai) mangrove forests

No.	Parameter	Pichavaram	Parangipettai	Mudasal Odai	Significance between sites
1.	Temperature (°C)	29.98 ± 2.39	29.60 ± 2.13	30.12 ± 2.28	NS
2.	Salinity (ppt)	22.93 ± 11.2	22.67 ± 9.26	22.26 ± 10.1	NS
3.	*p*H	08.08 ± 0.26	08.04 ± 0.24	08.13 ± 0.26	NS
4.	Humidity (%)	85.75 ± 5.17	86.67 ± 4.62	87.67 ± 3.82	NS
5.	Tidal spread (m)	18.19 ± 2.63	39.56 ± 3.50	53.87 ± 7.19	*
6.	Tidal height (cm)	88.41 ± 3.84	114.5 ± 9.89	112.6 ± 9.78	*
7.	Moisture (%)	20.13 ± 6.06	14.64 ± 2.30	12.68 ± 1.68	*
8.	Sand (%)	85.20 ± 3.88	88.03 ± 3.73	89.87 ± 2.88	*
9	Silt (%)	13.17 ± 3.32	10.52 ± 3.67	08.91 ± 3.27	*
10	Clay (%)	01.61 ± 0.90	01.45 ± 0.49	01.11 ± 0.40	*
11	THB ($x10^3$)	759.5 ± 150	518.92 ± 87.0	556.2 ± 129	**
12	Sugar (mg g^{-1})	0.340 ± 0.27	0.370 ± 0.84	0.320 ± 0.13	*
13	Amino acids (mg g^{-1})	10.25 ± 4.28	07.16 ± 1.14	07.79 ± 1.63	*
14	Tannins (mg g^{-1})	02.93 ± 1.92	02.26 ± 0.86	02.39 ± 0.81	NS
15	TOC (mg g^{-1})	03.85 ± 2.58	03.53 ± 1.27	03.59 ± 1.69	*
16	Nitrogen (mg g^{-1})	0.830 ± 0.23	0.600 ± 0.21	0.470 ± 0.10	*
17	Phosphorus (mg g^{-1})	0.640 ± 0.17	0.440 ± 0.14	0.330 ± 0.07	*
18	Potassium (mg g^{-1})	0.470 ± 0.10	0.270 ± 0.10	0.340 ± 0.12	**

Values are the average of twelve samples Â standard error.

**Values are significant at 1% and *at 5% level, and NS - not significant.

the planted mangroves, 19 year old mangroves showed higher levels of nitrogen, phosphorus and sugars than 9 year old mangroves. Thus mangrove plantation seemed to increase the nutrients by changing soil composition with high fine particles such as silt and clay. This increased level of nutrients was also revealed by the higher counts of total heterotrophic bacteria. The result indicated that mangrove planting induces the functional changes in the mangrove soil habitat.

Mangroves contribute to soil formation and help stabilize coastlines and serve as habitat for many marine organisms. In the pristine ecosystem (Hinchinbrook Channel, Australia), mangroves are reported to be the largest single source of organic carbon accounting for 56% of total carbon input (Alongi *et al.*, 1998). The deposited suspended matter is the dominant source of organic carbon and nitrogen in mangrove sediments (Bouillon *et al.*, 2003). The present study has proved that the mangrove planting improves habitats by increasing the fine soil particle deposition, moisture retention, nutrient accumulation, and total heterotrophic bacterial counts.

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Arbuscular Mycorrhizal Status and VAM Fungal Diversity in the Soils Polluted by Carpet Industries

Harbans Kaur Kehri*, Nidhi Sharma, Avinash Pratap Singh and Rani Mishra

Sadasivan Myco-Pathology Laboratory
Deapartment of Botany, University of Allahabad
Allahabad – 211002, Uttar Pradesh, India
**E-mail: kehrihk@gmail.com*

Abstract: A systematic survey of the metal polluted site of adjoining areas of Allahabad (Bhadoi), India was undertaken to assess the population and diversity of AM fungi in such soils and intensity of AM association in the roots of the plants growing in vicinity. A total of 15 species belonging to two genera of AM fungi were isolated from the different zones of the selected metal polluted sites. *Glomus* was recorded as the most dominant genus with 11 species, *viz. G. aggregatum, G. albidum, G. claroideum, G. constrictum, G. fasciculatum, , G. mosseae, G. occultum,* and 4 unidentified species named *Glomus* sp. 1 to 4, followed by *Acaulospora* with four species, *viz., A. bireticulata, A. laevis,* and 2 unidentified species named *Acaulospora* sp. 1 and 2, AM fungal diversity also showed a negative correlation with the magnitude of stress, as it increased from Zone I to Zone III at this site. *Glomus mosseae* and *G. aggregatum* were the most frequent species while *Glomus mosseae* was the most abundant species.

Keywords: AM Fungi, Spore population, diversity, metal pollution, carpet industry.

Over the past three decades, the effect of heavy metals on the environment has become an important and ever increasing field of study. Pollution by heavy metals is as old as the smelting of these elements by men. But pollution of biosphere by toxic metals has accelerated dramatically since the beginning of the industrial revolution. A number of industries pour their hazardous effluents into the soil, such as chemical and electronic industries mainly produce Hg; metallic, mining and smelting industries produces Pb, Cd, As, Hg, Fe and Ni; metallurgical industries produce As, Cd, Cr, Cu, Mn, Ni, Pb and Zn. The pulp and paper industry generates Zn, Cu, Cr, Ni, Al, Fe, and Mn. Other industries like textile, pesticides, paints, dyes, petroleum, steel, glass, and electroplating industries pour different sets of heavy metal containing effluents. Heavy metals are also generated by agricultural sources, fertilizers, pesticides and farmland manures from enriched federations. For a country like India with its high population density there is a great demand on land utilization for use of food, fodder, and fuel production, besides the need for settlement also. India, which constitutes only 2% of the world's total land, provides shelter to the 16% of the world's population. Because of this high man to land ratio, there is a considerable pressure on land on account of the competing land uses.

The AM technology has a great deal to contribute in improving the productivity and profitability of heavy metal polluted lands (Vodnik *et al.,* 1998). Before undertaking any reclamation programme of such lands the complete knowledge about the mycorrhizal status that is AM fungal spore population, their diversity and mycorrhizal intensity in the roots of plants growing in the vicinity of that area is essential. In view of this following study has been undertaken.

MATERIAL AND METHODS

A systematic survey of the metal polluted site Bhadoi (the adjoining area of Allahabad), India was undertaken to assess the population and diversity of AM fungi in such soils and intensity of AM association in the roots of the plants growing in vicinity.

Nutrient status of the soils of selected site: The site Bhadoi (25° 24' N, 82° 38' E) located near Allahabad, Uttar Pradesh, was selected for the survey. In Allahabad, Bhadoi industrial area is polluted by various types of dye and carpet industries. Analysis of the soil samples of all the zones of this site showed that this site had significantly high metal concentrations. At the site, large patches of unproductive fallow lands were found intermixed with the agricultural fields. The site was divided into three different zones consisting of grassy patches, scanty vegetation and cultivated fields.

Soil and root samples from this site were collected during summer (April - May,), rainy (August – September,) and winter (December–January) seasons. During each sampling, 200g soil was collected randomly from each zone at different depths *i.e.* 0-15cm, 15-30cm and 30cm below the surface. Root samples of the plants growing in different zones were also collected for the estimation of mycorrhizal infection.

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Analysis of Soil Samples: Collected soil samples were air dried, sieved and soil extract was prepared by the method of Adams *et al.* (1980). Soil pH and electrical conductivity (EC) were measured with a digital pH meter and a digital EC meter. Total organic carbon was estimated by the method given by Nelson and Sommers, (1982), phosphorus by Watanabe and Olsen, (1965).

AM spore population was determined in 50g air-dried soil in triplicates for each sample by wet sieving and decanting method (Gerdemann and Nicolson, 1963). Species were identified using the synoptic keys of Trappe, (1982), Schenck and Perez (1990) and INVAM species guide (http://invam.caf.wvu.edu).Spore density, frequency and relative abundance of AM fungi were expressed as follows:

Spore density = number of AM spores in 50g air dried soil

Frequency = (number of zones in which AM fungal species was observed/total number of zones) x 100%

Relative abundance = (number of spores of a AM fungal species at one site/total number of spores at that site) x 100%

Root samples of the plants along with their rhizospheric soils were collected. Samples of at least three individuals per plant species were collected and mixed. Samples were brought back to the laboratory and the roots of the plants along with the fine roots present in the rhizospheric soils were washed with tap water and processed for the determination of root colonization. Soil samples were air dried in shade at room temperature and sieved for the estimation of AM spore population and diversity.

Intensity of AM colonization in the root samples was determined by the method given by Phillips and Hayman (1970). Percent root bits colonized was calculated and the percent root length colonization was assessed by evaluating the colonized root tissue as a proportion of the total length of observed roots.

RESULTS AND DISCUSSION

Analysis of Soil Samples: The data of analysis of all the soil samples collected from different zones of the selected sites, *i.e.* Bhadoi has been presented in Table 1. The elemental analysis of the soil samples indicated that the soils pH of this site was high. The pH of the uncontaminated soil was 6.9, while it ranged from 7.7 (Zone III) to 8.9 (Zone I) at Bhadoi. However, electrical conductivity (EC) was not higher than the normal range at this site. EC ranged from 0.80 m. mhos cm^{-1} (Zone III) to 0.19 m. mhos cm^{-1} (Zone I) at Bhadoi, while EC of uncontaminated soil is 0.13 mhos.cm^{-1}

The nutrient status of the soil samples of this site was very poor. The organic carbon contents were low in all the samples analyzed. Organic carbon ranged from 0.03% (Zone I) to 0.40% (Zone III) at Bhadoi. 0.73% organic carbon was present in the uncontaminated soil. The soils were also deficient in phosphorus and potassium content. Available phosphorus, estimated in terms of P_2O_5, ranged from 14 kg/ha (Zone I) to 29 kg/ha (Zone III) at Bhadoi. Potassium content, estimated in terms of K_2O, ranged from 93 kg/ha (Zone I) to 252 kg/ha (Zone III) at Bhadoi. Phosphorus and potassium content in uncontaminated soil was 73 kg/ha and 289 kg/ha respectively. Analysis of the soil samples of this site showed that this site had significantly high metal concentration. Heavy metal concentration of different metals *viz.* Zn, Fe, Cu, Mn, Pb, Cd, Ni, and Co was analyzed in the soils of this site. The metal analysis of all the soil samples collected from different zones of the selected site, *i.e.* Bhadoi has been presented in Table 2. Concentration of Zn, Fe, Cu, Mn and Cd in the uncontaminated soil was 20.16 ppm, 67.24 ppm, 6.0 ppm, 23.53 ppm, and 1.53 ppm respectively, while Pb, Ni and Co were present in traces. Bhadoi site had received the highest Zn, Cu, Mn, Cd, Ni, and Co concentrations.

Vegetation Composition in the Different Zones of the Selected Site: The data of vegetation composition in the different zones of the selected site, *i.e.* Bhadoi has been presented in Table 3. A total of 17 plant species belonging to 11 families were identified from the different zones of the selected site. Minimum vegetation was recorded in Zone III. Grasses such as *Euphorbia hirta L.*, *Sida sp.*, *Cynodon dactylon* (L.)Pres, *Panicum sp.* and *Solanum nigrum* were the most dominant vegetation in these zones. However, Zone III, where cultivation was being practiced, was mainly dominated by the cultivated crops. The largest family were Poaceae and Asteraceae accounting for 27.2% of total flora recorded, followed by Euphorbiaceae and Fabaceae accounting for 18.2%. Zone I and Zone II were dominated by the members of the family Asteraceae, Caesalpinioideae, Euphorbiaceae, Fabaceae, Malvaceae, Nyctaginaceae, Poaceae and Solanaceae. *Brassica campestris* L., *Cajanus cajan* (L.) Huth., and *Triticum aestivum* L. were the most dominant crops being cultivated in Zone III of the selected site.

AM Association in the Roots of the Plants Growing in Different Zones of the Selected Site: Data of the AM Mycorrhizal intensity in the roots of the plants growing in different zones of the selected site in different seasons has been presented in Table 4. All the plants showed association in their roots but except for the plant species belonging to the families Brassicaceae, Chenopodiaceae and

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Table 1. Edaphic features of the metal polluted soils of different zones collected from the selected site i.e. Bhadoi of Allahabad Uttar Pradesh

Sites/Zones	pH	EC(m.mhos.cm^{-1})	Organic carbon(%)	Phosphorus(kg/ha)	Potassium (kg/ha)
Zone I	8.90	0.80	0.03	14.00	93.0
Zone II	8.70	0.38	0.36	29.00	130.0
Zone III	7.70	0.19	0.40	29.00	252.0
Control	6.90	0.13	0.73	73.00	289.0

Table 2. Concentration of different metals in the metal polluted soils of different zones collected from the selected site of Allahabad ,i.e. Bhadoi Uttar Pradesh

Zones	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)	Pb (ppm)	Cd (ppm)	Ni (ppm)	Co (ppm)
Zone I	129.36	329.36	125.7	41.73	99.36	20.76	38.23	1.0
Zone II	107.8	168.53	16.9	28.7	12.70	15.40	14.76	0.80
Zone III	30.30	72.80	14.0	28.0	10.43	3.67	1.43	0.10
Control	20.16	67.24	6.0	23.53	-	1.53	-	-

Table 3. Vegetation composition of different zones of heavy metal polluted soils at Bhadoi near Allahabad.

Family	Plants	Vegetation composition		
		Zones		
		I	II	III
Acanthaceae	*Peristrophe bicalyculata* Nees.	-	+	-
Asteraceae	*Eclipta sp.*	+	+	-
Asteraceae	*Parthenium sp.*	+	+	-
Asteraceae	*Xanthium sp.*	+	+	-
Brassicaceae	*Brassica campestris* L.	-	-	+
Caesalpinioideae	*Cassia sp.*	+	+	-
Euphorbiaceae	*Croton bonplandianum* Baill.	+	+	-
Euphorbiaceae	*Euphorbia hirta* L.	+	+	+
Fabaceae	*Cajanus cajan* (L.)Huth.	-	-	+
Fabaceae	*Sesbania sesban (L.) Merr.*	+	+	-
Malvaceae	*Sida sp.*	+	+	+
Nyctaginaceae	*Boerhaavia diffusa* L.	+	+	-
Papavaraceae	*Argemone mexicana* L.	-	+	+
Poaceae	*Cynodon dactylon* (L.) Pres.	+	+	+
Poaceae	*Panicum sp.*	+	+	+
Poaceae	*Triticum aestivum* L.	-	-	+
Solanaceae	*Solanum nigrum*	+	+	+

Cyperaceae. However, the intensity of the mycorrhization varied with the plant species, magnitude of the stress and seasonal variations. Hyphae, vesicles, arbuscules and intramatrical spores characteristic of AM fungi were observed in the roots of the plants. Maximum infection in the root was recorded in *Cajanus cajan* (L.) Huth. Likewise minimum infection was recorded in *Xanthium sp.* In general, the intensity of AM infection showed a negative correlation with the magnitude of heavy metal stress, as it increased from Zone I to Zone III at this site. Mycorrhizal intensity ranged from 0-18% in Zone I, 0-30% in Zone II, and 0-70% in Zone III. Maximum AM infection was recorded in winter season. However, no significant pattern of mycorrhization could be traced in relation to the seasonal variation. Mycorrhizal intensity ranged from 10-70% during winter season, 4-44% during rainy season, 8-57% during summer season.

Spore Population, Diversity, Distribution and Abundance of AM Fungi in Different Zones of the Selected Site: The presence of the AM fungi was recorded in all the zones at the site, their population and diversity varied along with the magnitude of stress and the seasonal variations.

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AM spore population also showed a negative correlation with the magnitude of stress, as it increased from Zone I to Zone III at the site . Average AM spore population was at Bhadoi 8.0, 21.0 and 30.0 spores/50g air dried soil in Zone I, Zone II and Zone III respectively. Significant variation was recorded in the AM spore population in relation to the seasonal changes. Maximum spore population was recorded in winter and minimum in summer. During winter season, spore population ranged from 11-49 spores/50g air dried soil while during rainy and summer season, it ranged from 9-25 spores/50g air dried soil and 4-16 spores/ 50g air dried soil respectively (Table 5 and 6).

A total of 15 species belonging to two genera of AM fungi were isolated from the different zones of the selected metal polluted sites. *Glomus* was recorded as the most dominant genus with 11 species, *viz. G. aggregatum, G. albidum , G. claroideum, G. constrictum, G. fasciculatum, , G. mosseae, G. occultum*, and 4 unidentified species named *Glomus* sp. 1 to 4, followed by *Acaulospora* with four species, *viz., A. bireticulata, A. laevis*, 2 unidentified species named *Acaulospora* sp. 1 and 2.

Maximum diversity of AM fungi was recorded in zone III, while the minimum in Zone I in all the three season. AM fungal diversity also showed a negative correlation with the magnitude of stress, as it increased from Zone I to Zone III. Maximum diversity of AM fungi was recorded in winter season followed by rainy and summer season. However, no significant seasonal variations were recorded in diversity. Frequency of the AM fungi, ranged from 22.2 to 88.9%. *Glomus mosseae* and *Glomus aggregatum* were the most frequent species, while *A. bireticulata* and *Acaulospora sp.*1 was the least frequent. Relative abundance of AM fungi, ranged from 1.1 to 22.0%. Here *Glomus mosseae* was the most abundant species; followed by *Glomus aggregatum*, while *A. bireticulata* and *Acaulospora sp.*1 was the least abundant.

The results of the present investigation show the detrimental effect of metal contaminated soils on the AM spore population, distribution and diversity. All were found decreasing significantly from zone III to zone I at this site. These findings are in conformity with the earlier reports of Shetty *et al.* (1995), Daniell *et al.* (2001) and Alves da Silva *et al.* (2005) where less spore population was recorded in the metal contaminated soils. It may be due to the fact that heavy metals can inhibit the spore germination (Hepper and Smith, 1976), and growth of the extraradical hyphae (del Val *et al.*, 1999). The total number of AMF spores strongly decreased with the addition of increasing amounts of heavy metals, but the AMF spores never disappeared completely in soils amended with the highest rates of metal, suggesting a certain adaptation of these indigenous AMF to such environmental stress. Decrease in AMF diversity

Table 4. Seasonal variation in the mycorrhizal intensity in the roots of plants growing in different zones of metal polluted soils of Bhadoi site (April- January)

Plants/Seasons/Zones	Mycorrhization (% Root bits Infected)								
	Summer (Apr-May)			Rainy (Aug-Sep)			Winter (Dec-Jan)		
	I	II	III	I	II	III	I	II	III
Argimone mexicana L.	-	-	-	-	23	44	-	-	-
Boerhaavia diffusa L	-	-	-	-	15	-	12	23	-
Brassica campestris L.	-	-	-	-	-	-	-	-	0
Cajanus cajan (L.) Huth.	-	-	57	-	-	-	-	-	70
Cassia sp.	0	11	-	4	18	-	10	22	-
Croton bonplandianum Baill.	-	19	-	12	25	-	18	25	34
Cynodon dactylon (L.) Pres.	0	0	15	0	0	18	0	24	-
Eclipta sp.	-	13	-	0	13	-	0	28	-
Euphorbia hirta L.	-	-	-	10	28	33	15	15	-
Panicum sp.	8	10	18	-	-	-	-	-	-
Parthenium sp.	0	12	-	16	20	-	18	18	-
Peristrophe bicalyculata Nees.	-	-	-	-	22	-	-	-	-
Sesbania sesban (L.) Merr.	0	-	-	-	24	-	-	30	10
Sida sp.	0	0	0	0	12	18	15	10	-
Solanum nigrum	0	-	-	11	10	-	-	13	64
Triticum aestivum L.	-	-	-	-	-	-	-	-	-
Xanthium sp.	-	-	-	8	13	-	-	-	

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and population may have resulted from a fungitoxic effect of metals, causing certain AMF species inability to colonize the root system and/or to multiply in the rhizosphere. Only AMF species better adapted to the disturbance produced by the addition of metals would overcome the stress situation and complete their life cycles (Corbett *et al.*, 1996; del Val *et al.*, 1999). High pH, poor plant diversity and low vegetation in these soils may severely restrict colonization and diversity of AM mycorrhizae (Alves da Silva *et al.*, 2005). In the present study, lowest AMF density and diversity at Zone I of Bhadoi site may be due to the high metal concentration, high pH, low nutritional status and low aboveground vegetation.

It is also reported that the AM spore population and root colonization pattern changes with seasonal variation and host plant phenology (He *et al.*, 2002; Bohrer *et al.*, 2004; Alves da Silva *et al.*, 2005). Patterns of seasonal changes in mycorrhizal intensity were more obvious in the annuals in comparison to perennials. Although no significant correlation could be established in the present study between the mycorrhizal intensity and seasonal variation, however, in general, mycorrhizal intensity was always higher in winter season. The highest degree of colonization of annuals in winter, i.e. during their flowering period, may have a possible explanation of increasing requirements of nutrients and water at this stage of growth (Shi *et al.*, 2007). Contrary to this, significant variation was recorded in spore population in relation to the seasonal changes. Maximum spore population was recorded in winter and minimum in summer. It has been observed that the number of spores increases after a period of maximum root growth. Studies by various authors have shown maximum spore count in winter (21-25°C) and minimum in monsoon (28-34°C) and summer (28-42°C) months (Saif and Khan, 1975; Giovannetti, 1985; Singh and Varma, 1985; Sylvia, 1986). The majority of the plant species growing on metal contaminated soils studied was herbaceous. Similar observations were also made by other researchers (Leung *et al.*, 2007).

Further, AM fungi differ in their tolerance to adverse physical and chemical properties of soil (Juniper and Abott, 1993; Aliasgharzadeh *et al.*, 2001). In the present study, genus *Glomus* was the most dominant, a result in agreement with previous studies (Pawlowska *et al.*, 2000; Turnau *et al.*, 2001; Alves da Silva *et al.*, 2005). Predominance of *Glomus* species may be attributed to the fact that these are the most widespread AM fungi (Mosse, 1973). These are also resistant to the metal concentration (Gaur and Adholeya, 2004). In the present study, 11 species of *Glomus viz.*, *G. aggregatum, G. albidum, G. claroideum*

Table 5. Seasonal variation in the population size and diversity of AM fungi in different zones of metal polluted soils of Bhadoi site (April - January).

AM Fungi /Seasons/Zones	AM POPULATION SIZE/DIVERSITY(/50g soil)								
	Summer (Apr-May)			Rainy (Aug-Sep)			Winter (Dec-Jan)		
	I	II	III	I	II	III	I	II	III
A. bireticulata Rothwell & Trappe	-	-	-	-	1	-	-	1	-
A. laevis Gerdemann & Trappe	-	-	1	-	1	1	-	3	3
*Acaulospora sp.*1	1	1	-	2	-	1	-	2	5
Acaulospora sp.2	-	-	-	-	1	-	-	1	-
G. aggregatum Schenck & Smith	-	3	2	2	2	5	3	6	8
*G. albidum*Walker & Rhodes	1	-	1	-	2	-	-	4	-
G. claroideum Schenck & Smith	-	3	2	-	2	3	-	5	6
G. constrictum Trappe	1	-	-	1	-	3	1	2	4
G. fasciculatum (Thaxter) Gerdemann & Trappe	-	2	-	1	1	-	1	3	3
G. mosseae (Nicol. & Gerd.) Gerdemann & Trappe	-	2	4	3	4	7	4	6	9
G. occultum Walker	-	1	-	-	1	-	-	-	3
Glomus sp.1	1	-	2	-	-	2	-	-	2
Glomus sp.2	-	-	1	-	-	1	2	-	2
Glomus sp.3	-	-	1	-	-	1	-	-	4
Glomus sp.4	-	1	2	-	1	1	-	1	-

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Table 6. Frequency distribution and relative abundance of AM fungi isolated from heavy metal polluted soils at Bhadoi near Allahabad.

AM Fungi/Zones	AM frequency distribution/ relative abundance				
	I	II	III	Frequency	Relative abundance
Acaulospora laevis Rothwell and Trappe	-	+	+	56.6	5.1
A. bireticulata Gerdemann and Trappe	-	+	-	22.2	1.1
Acaulospora sp. 1	+	+	+	66.6	6.8
Acaulospora sp. 2	-	+	-	22.2	1.1
Glomus aggregatum Schenck and Smith	+	+	+	88.9	17.5
G. albidum Walker and Rhodes	+	+	+	44.4	4.5
G. claroideum Schenck and Smith	-	+	+	66.7	11.8
G. constrictum Trappe	+	+	+	66.7	6.8
G.fasciculatum Becker and Gerdemann	+	+	+	66.7	6.2
G.mosseae (Nicol. AndGerd.) Gerdemann and Trappe	+	+	+	88.9	22.0
G. occultum Walker	-	+	+	33.3	2.8
Glomus sp. 1	+	-	+	44.4	3.9
Glomus sp. 2	+	-	+	44.4	3.4
Glomus sp. 3	-	-	+	33.3	3.4
Glomus sp. 4	-	+	+	55.6	3.4

G. constrictum, G. fasciculatum, G. mosseae, G. occultum, and 4 unidentified species named *Glomus* sp. 1 to 4 were found. *Glomus mosseae* and *G. aggregatum* are the most frequent and abundant. The results were in accordance to the earlier reports (Gaur and Adholeya, 2004; Alves da Silva *et al.*, 2005). Daniell *et al.* (2001) suggested one reason for this may be ability of the Glomaceae (unlike Gigasporaceae) to recolonize roots from mycelia fragments, coupled with the ability of *Glomus* species, unlike *Gigaspora* or *Scutellospora*, readily to establish anastomoses between separate mycelia. These species may therefore, be particularly well adapted to recolonise roots following disruption of the soil mycelium. Most of these AM fungal species are small in size and have thick walls. These characters may provide them more adaptability under stress conditions. Similar results indicating a tendency in species composition towards mostly small spored fungi belonging to the genus *Glomus* have previously been reported in the stressed habitats (Janardhanan *et al.*, 1994; Wang *et al.*, 2004; Shi *et al.*, 2007), as these species may be more adaptable in adjusting patterns of sporulation to environmental stress conditions (Jacobson, 1997).

It has been widely accepted that mycorrhizal fungi are able to adapt to edaphic conditions (Bundrett *et al.* 1996; Estaún *et al.*, 1997; del Val *et al.*, 1999; Weiersbye *et al.*, 1999; Enkhtuya *et al.*, 2002; Bi *et al.*, 2003). It might be expected that AM fungal isolates adapted to local soil conditions can stimulate plant growth better than non-indigenous isolates. Indigenous AM fungal ecotypes result from long-term adaptation to soils with extreme properties. Therefore, isolation of indigenous stress-adapted AM fungi can be a potential biotechnological tool for inoculation of plants in disturbed ecosystems (Dodd and Thompson, 1994; Caravaca *et al.*, 2003).

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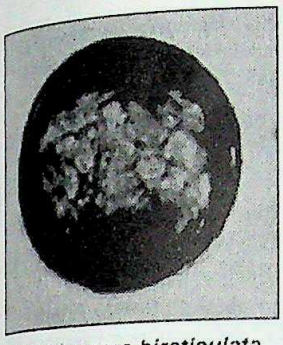
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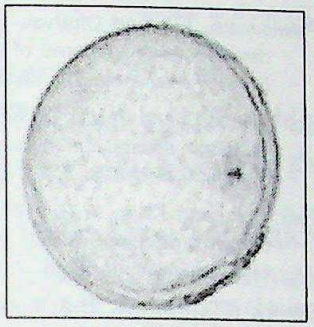
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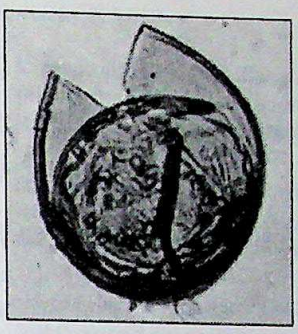
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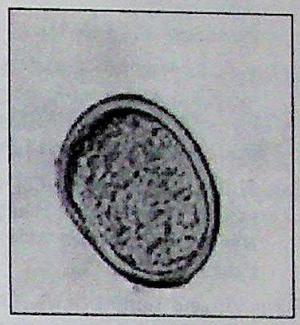
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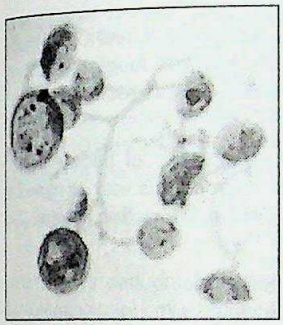
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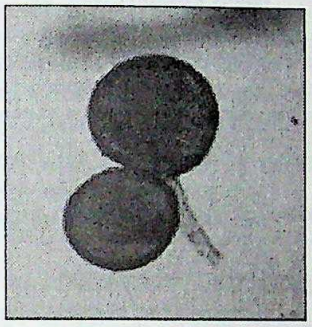

Acaulospora bireticulata

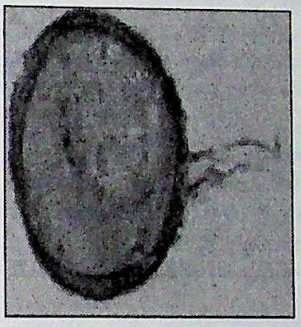

Acaulospora laevis

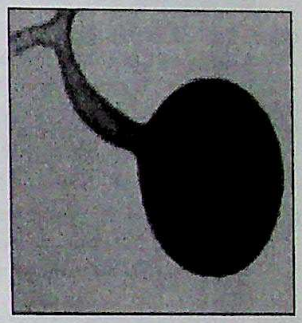

Acaulospora sp. 1

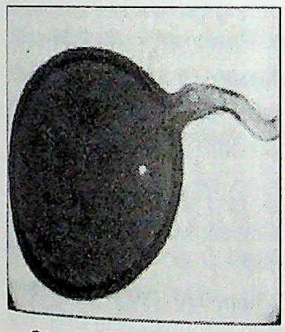

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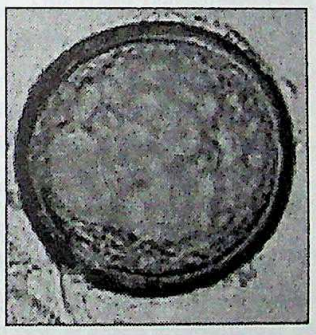

Glomus aggregatum

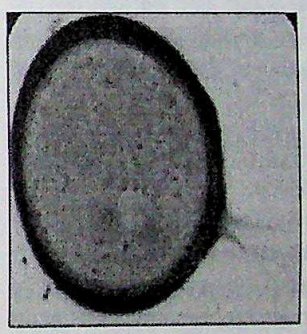

Glomus albidum

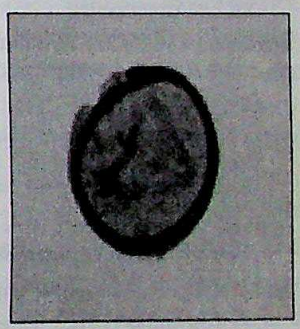

Glomus claroideum

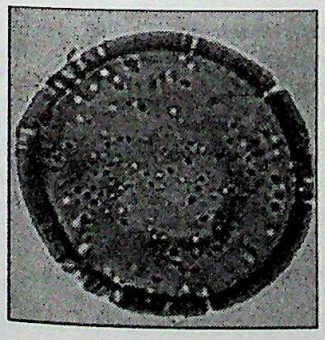

Glomus constrictum

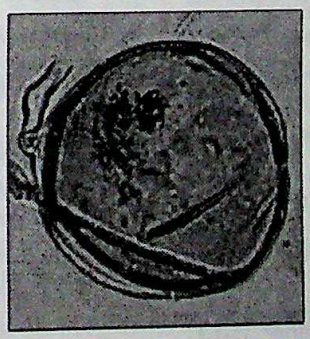

Glomus fasciculatum


Glomus mosseae


Glomus occultum


Glomus sp. 1


Glomus sp. 2


Glomus sp. 3

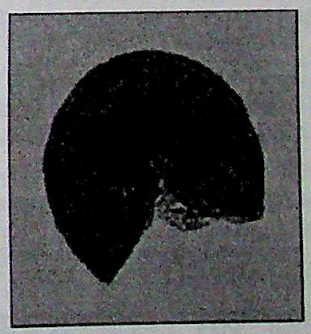

Glomus sp. 4

Plate - 1

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Indian Journal of Ecology

Effect of Storage Period on the Nutrient Composition of Value Added Products for Pregnant Women

B. Sadana*, P. Bakhetia and R. Aggarwal

Department of Food & Nutrition, College of Home Science
Punjab Agricultural University, Ludhiana-141 004, India
**E-mail: sadana_pau@yahoo.com*

Abstract: Five value added products namely *Pinni*, *Cauliflower green mathi*, *Panjiri*, *Channa mix* and *Marunda* were developed for pregnant women. Among the products, *Channa Mix* and *Marunda* were found to be highly acceptable with a mean score of 4.85 each followed by *Pinni* having score of 4.56 when assessed at 5.00 point hedonic scale. The energy content ranged from 405 to 469 kcal per 100g on dry weight basis in developed products. Iron and β-carotene were found to be maximum in *Channa mix* having values as 29.6 mg and 10161µg/100g, respectively. Free fatty acid, peroxide value, reducing and non-reducing sugars increased significantly with an increase in storage period.

Keywords: Value added foods, Organoleptic evaluation, Peroxide value, Free fatty acid

The problem of food and nutrition security is of paramount importance in India. The diets consumed by a large majority of population in India are lacking in number of dietary essentials, resulting in widespread prevalence of malnutrition. Iron and vitamin A deficiencies are two major nutritional health problems affecting the vulnerable groups in many developing countries. Based upon age, sex, physiologic status the groups at greatest risk are pregnant women, infants and toddlers and pubertal children. An estimated 5000 million people worldwide are iron deficient and 52% of the world's pregnant women are thought to be anemic (WHO,1998). Improvement in supply and consumption of iron rich foods and enhancing the bioavailability of iron from foods are important strategies to improve the iron status of vulnerable groups. In India, it is observed that diets among women from poorer groups are essentially similar during pre-pregnant and pregnancy period. Consequently, there is widespread maternal malnutrition leading to high prevalence of low birth weight infants and very high maternal mortality (ICMR 2001). Keeping in view the health status of pregnant women, the study was carried out to develop β-carotene and iron rich value added supplementary foods for pregnant women and also to determine the effect of storage on their nutrient composition.

MATERIAL AND METHODS

For the preparation of value added products, samples of wheat (*Triticum aestivum*), soybean (*Glycine max merr.*), black gram dhal (*Phaseolus mungo roxb*), roasted channas (*cicer arietinum*), cauliflower leaves (*Brassica oleracea var. botrytis*) and carrot (*Daucus carota*) were purchased from the local market. Leaves and carrots were washed thoroughly with tap water to get rid of any dirt. Leaves were chopped, carrots were grated and dried to constant weight in hot air oven at 60°C. The dried leaves and carrots were then powdered in electric grinder. The wheat and soybean were soaked separately in water for 10-12 hours, respectively and then kept in incubator at 25°C for germination. Germinated grains were dried at 60°C and then grinded in electric grinder. Value added products namely *Pinni*, *Panjiri*, *Cauliflower green mathi*, *Channa mix* and *Marunda* were developed in the laboratory (Table 1). Prepared products were stored in air tight containers at room temperature. Sensory evaluation of products was carried out on 5.00 point hedonic scale at an interval of 0,30 and 60 days by a panel of 12 judges using numerical score test for appearance, color, taste, flavor, doneness, texture and overall acceptability (Swaminathan, 1987). Products were analyzed for proximate composition (AOAC, 1980), iron and calcium (AOAC,1990) and β-carotene (Rao,1967).Total carbohydrate content was calculated by difference and energy content was calculated by factorial method (AOAC,1990). Nutritional evaluation in relation to storage period (0 to 60 days at an interval of 15 days) was carried out for free fatty acid and peroxide value (Cox and Pearson, 1962), total sugar (Hedge and Fofreiter, 1962), reducing sugar (Nelson, 1944) and non- reducing sugar by the difference in the concentration of total sugar and reducing sugar. Differences among chemical constituents of each product were statistically tested using analysis of variance and F-values.

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RESULTS AND DISCUSSION

Among various products tested, *Marunda* and *Channa Mix* obtained maximum scores for over all acceptability as 4.85 at 0 day interval followed by *Pinni*, *Panjiri* and *Cauliflower green mathi* (Fig. 1). Organoleptic scores revealed that the rating of all the products ranged from good to very good. Scores for individual parameters i.e. appearance, taste, flavour and overall acceptability decreased with an increase in storage duration and the decrease was found to be statistically significant ($p<0.05$).

The protein content of products varied from 7.3 to 25.6 being minimum in *Marunda* and maximum in *Channa Mix* due to the difference in the amount of ingredients used for their preparation (Table 2). *Channa Mix* had significantly higher protein as compared to other value added products. Ash content ranged from 1.4 to 2.8 g being minimum in *Panjiri* and *Channa mix* and maximum in *Cauliflower green mathi*. Higher ash content of *mathi* is attributed to the incorporation of cauliflower green powder having higher mineral content. Fat content was maximum in *Cauliflower green mathi* (25.3g) and minimum in *Channa mix* primarily due to differences in amount of fat being added in *mathi* dough and secondly *mathi* being deep fried. *Marunda* developed as a supplementary value added food provided minimum energy as 405 kcal while *Cauliflower green mathi* had the maximum energy value as 469 kcal on percent basis. Higher energy in *mathi* could be attributed to more amount of fat used in its preparation. Findings are supported by Lakshmi and Prakash (2000) who reported that deep fat fried snacks are dense sources of energy. The calcium content was found to be maximum in *Marunda* (3157 mg) followed by *Channa mix* (2814 mg) while the least was found in *Pinni* as 234 mg/100g. *Channa mix* had maximum content of iron (29.3mg/100g) followed by *Panjiri* and *Cauliflower green mathi*. The β-carotene content was highest in *Channa mix* (10161µg) and minimum in *Panjiri* (1021µg). The higher iron and β-carotene content in the developed products can be attributed to addition of cauliflower leaf powder (CLP) which is rich source of iron and β-carotene. Singh et al (2005) reported that dry cauliflower leaf powder contains 66.8mg/100g of iron and 45.6mg/100g of β-carotene. Reema et al (2004) also reported an increase in iron and β-carotene content of supplementary foods prepared from germinated cereals and legumes.

The length of storage period altered the chemical composition of prepared products. Foods when stored for two months, showed the impact of storage on various parameters (Table 3). The free fatty acid content of the freshly prepared products was found to be highest in *Pinni* (0.26%) and lowest in *Channa mix* (0.06%) The free fatty acid content increased from 0.11 to 0.44% in *Cauliflower green mathi*, 0.26 to 0.36% in *Pinni*, 0.20 to 0.35% in *Panjiri* , 0.06 to 0.13% in *Channa mix* and 0.07 to 0.31% in *Marunda* from 0 day to 60th day, respectively. The acid value is an indicative of free fatty acid present in the oil. Higher the acid value more will be the free fatty acid content and shelf life will thus be less. The increase in free fatty acid content during storage was found to be statistically significant except for increase in *channa mix*. The increase in free fatty acid content of *Channa mix* and *Marunda* was found to be less as compared to the other products. The reason could be non addition of visible fat in these two products. Hydrogenated fat was used in *Pinni* and *Panjiri* and the free fatty acid content of both these products even on 60th day of storage was found to be in range i.e 0.6 as given by FAO(1997)/ AOAC (2000). Results showed that with an increase in storage duration the free fatty acid content also increased significantly. The peroxide value of the products ranged from 1.98 to16.44 meqO_2/kg fat on 0 day and 30.5 to 59.7 meqO_2/kg fat on the 60th day of storage period. The highest percent increase in peroxide value during storage was in *Marunda* (1447%) and lowest in *Channa mix* (85.5%) with significant differences. Sweet products were analyzed for sugar content. The reducing sugar of *Panjiri* on 0 day was found to be minimum (0.21%) which increased to 3.42% on 60th day of storage while the maximum value for 0 and 60th day was found to be for *Channa mix* i.e. 8.69% and 10.98%, respectively. Results are in accordance with Rani and Bhatia (1985) who also reported an increase in the reducing sugars of pear candy during storage of 16 weeks at 37° C and 24 weeks at ambient temperature. This increase according to them may be because of increased inversion of sugars.

The non-reducing sugar content ranged from 98 to 211% on 0 day and 155 to 232% on the 60th day with minimum value for *Pinni* and maximum for *Marunda* on 0 day and *Channa mix* for 60th day. The total sugar content was maximum for *Marunda* on 0 day (217%) while on 60th day *Channa mix* had maximum content (244%). The reason for more of sugars in *Channa mix* and *Marunda* might be the addition of jaggery instead of sugars. During storage the sugar content of all the products increased significantly ($P\leq0.05$). Findings are in accordance with that of Tripathi et al (1988) who reported that the total sugar continued to increase in amla preserve during storage. This might be attributed to increased degree of inversion of sugars on account of higher fixed acidity. Sugar content changes were recorded at the storage interval period of 0, 45, 90 and 135 days, respectively. Keeping in view the RDA of various

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Table 1. Ingredients and methods for preparation of germinated supplementary products

Name of Recipe	Description of Recipe	Ingredients used	Weights of Ingredients (g)	Cooked weight (g)	No. of Serving
Cauliflower green mathi	Roast and grind dhal. Sieve germinated wheat flour, dehusked black gram pulse and CLP and salt. Rub a little fat in the mixture. Knead into hard dough with the help of water. Take a small portion of dough and shape it like round flattened ball and put a black pepper in the center of each flattened ball. Deep fry it till golden brown.	Refined wheat flour Dehusked black gram pulse CLP Fat in dough Salt Black pepper	120 50 10 20 & for frying to taste to taste	200	2.5
Pinni	Roast the germinated flour with fat on slow fire in pan for few minutes till golden brown. Add the roasted groundnuts. Switch off the gas. Mix the rest of ingredients and shape into small balls.	GWF GSF Sugar Vanaspati fat Roasted groundnuts CP	40 20 20 30 5 5	120	2
Panjiri	Heat oil in a pan. Add germinated flour and roast it. Add powdered sugar and groundnuts. Finally remove it from fire.	GWF GSF Ghee Groundnut (roasted & powdered) Sugar CP	30 15 20 5 30 5	105	1
Channa Mix	Prepare syrup with Jaggery. Add roasted channas and puffed rice into the syrup. Add carrot and dried cauliflower leaf powder. Mix well.	Puffed Rice Jaggery Roasted channas CP CLP	120 200 60 20 20	400	8
Marunda	Melt jaggery in heated oil. Add dried greens and cook for 2-3 minutes. Add puffed rice and roasted pulse. Mix thoroughly and immediately give shape.	Puffed rice Roasted Chana pulse CLP Cooking oil Jaggery	100 100 25 30 200	400	4

GWF: Geminated Wheat Flour, GSF: Germinated Soyabean Flour, CP: Carrot Powder, CLP: Cauliflower Leaf Powder

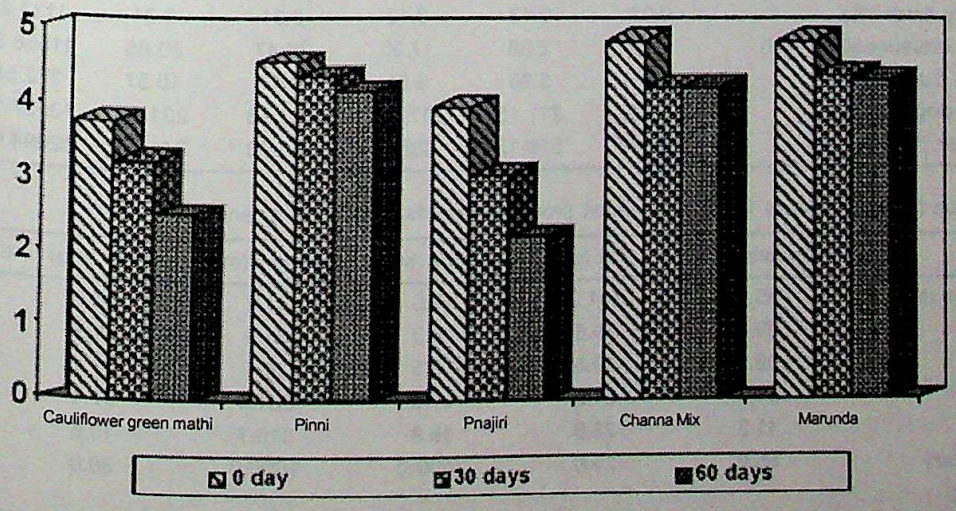


Fig. 1 Effect of storage on mean sensory scores

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Table 2. Nutrient composition of Value Added Products (% Dry matter basis)

S.No	Nutrient	Cauliflower green mathi	Pinni	Panjiri	Channa mix	Marunda	CD at 5% level
1	Ash(g)	2.8	1.7	1.4	1.4	1.9	0.22
2	Protein(g)	25.6	25.9	25.5	33.4	7.3	0.83
3	Fat(g)	25.3	19.2	14.9	5.3	7.0	0.53
4	Fiber(g)	0.1	1.7	0.7	4.8	0.8	0.04
5	CHO(g)	34.6	46.5	52.0	55.1	72.0	0.33
6	Energy(Kcal)	469.0	463.0	445.0	423.0	405.0	0.53
7	Iron(mg)	17.1	12.0	19.4	29.3	6.3	0.53
8	Calcium(mg)	472.0	234.0	311.0	2814.0	3157.0	0.57
9	β-carotene(μg)	2983.0	6631.0	45.0	10161.0	2155.0	2.66

Table 3. Effect of storage duration on different parameters of products

S. No.	Parameters	Storage Duration (Days)					F-ratio	CD at 5% level
		0	15	30	45	60		
Cauliflower green mathi								
1	Free Fatty Acids (%)	0.11	0.13	0.18	0.31	0.44	593.04*	0.02
2	Peroxide value(meqO_2/kg fat)	4.93	6.06	12.86	21.90	36.20	26719.55*	0.25
Pinni								
1	Free Fatty Acids (%)	0.26	0.28	0.33	0.33	0.36	35.70*	0.02
2	Peroxide value(meqO_2/kg fat)	6.87	8.35	14.70	18.16	59.70	6913.72*	0.83
3	Reducing Sugar(%)	1.83	1.90	2.03	3.71	4.67	6957.18*	0.5
4	Non-reducing sugar (%)	98.00	100.10	110.90	143.80	155.80	1852.27*	1.94
5	Total sugar (%)	99.50	102.00	113.00	147.50	160.50	34061.27*	0.47
Panjiri								
1	Free Fatty Acids (%)	0.20	0.25	0.25	0.33	0.35	47.90*	0.03
2	Peroxide value(meqO_2/kg fat)	10.64	13.14	25.87	47.17	50.22	8720.99*	0.63
3	Reducing Sugar(%)	0.21	0.24	2.61	3.27	3.42	141.42*	0.42
4	Non-reducing sugar (%)	112.66	114.76	120.88	130.73	161.58	63440.14*	0.22
5	Total sugar (%)	114.70	115.00	123.50	134.00	165.00	882.56*	2.21
Channa mix								
1	Free Fatty Acids (%)	0.06	0.08	0.09	0.13	0.13	2.32^{NS}	—
2	Peroxide value(meqO_2/kg fat)	16.44	18.79	19.60	26.48	30.50	3168.60*	0.33
3	Reducing Sugar (%)	8.69	8.96	10.60	10.89	10.98	59.16*	0.45
4	Non-reducing sugar (%)	195.60	196.64	203.15	226.61	232.77	63440.14*	0.22
5	Total sugar (%)	204.98	205.60	213.75	237.50	243.75	3427.28*	0.98
Marunda								
1	Free Fatty Acids (%)	0.07	0.13	0.13	0.31	0.31	1133.83*	0.01
2	Peroxide value(meqO_2/kg fat)	1.98	2.08	17.90	26.47	30.65	11566.33*	0.39
3	Reducing Sugar (%)	5.81	5.98	8.01	9.47	10.57	372.58*	0.34
4	Non-reducing sugar (%)	211.00	211.15	212. 98	220.53	231.31	13537.17*	0.23
5	Total sugar (%)	216.98	218.13	220.00	230.00	241.88	12894.06*	0.29

Table 4. Contribution (%) of nutrients from value added products towards pregnant women.

Food	Protein (g)	Fat (g)	Energy (kcal)	Calcium (mg)	Iron (mg)	β –carotene (μg)
Cauliflower green mathi	39.4	101.2	19.5	47.2	45.0	124.0
Pinni	39.8	76.8	19.3	23.4	31.6	276.0
Panjiri	39.2	59.6	18.5	31.1	51.1	42.5
Channa mix	51.4	21.2	17.6	281.4	77.1	423.0
Marunda	11.2	28.0	16.9	315.7	16.6	90.0
Recommended Dietary Allowances (RDA)	65.0	25.0	2400.0	1000.0	38.0	2400.0

Value given in the Table represent percent of RDA

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nutrients recommended for pregnant woman moderate worker, it was observed that developed products provided 11.2 to 51.4% protein, 21.2 to 101.2 % fat, 16.9 to 19.5% energy, 23.4 to 315.7% calcium, 16.6 to 77.1% iron and 89.8 to 423.4% β-carotene respectively provided 100g of recipe is consumed daily (Table 4).

The study concluded that products developed from dried cauliflower leaves were organoleptically acceptable and contained appreciable amount of protein, energy, iron, β-carotene and calcium. These products can be stored effectively for a period of two months without much change in their overall acceptability, free fatty acids, sugars and peroxide value. These products if supplemented in diet can help to meet the recommended dietary allowances of iron and β-carotene and also help in combating iron and vitamin A deficiency and thereby help in improving the health status of pregnant women.

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Relationship of Obesity and Osteoporosis in Pre and Post Menopausal Women

Dipti Chowdhary*, Jasvinder Kaur Sangha and Kiran Grover

Department of Food and Nutrition, Punjab Agricultural University, Ludhiana-141004, India.
**E-mail Address: dipti@pau.edu*

Abstract: The study was undertaken to determine the effect of overweight and obesity on the Bone Mineral Density (BMD) of the pre and post menopausal women. Subjects were divided into two groups according to their menopausal status in pre and post menopausal group and their BMD was measured by Bone Ultrasonometer. Body composition was analyzed and anthropometric measurements were taken by standard methods. The findings indicated that, among pre menopausal women, 57.5% had normal BMD, 40% had osteopenia and only 2.5% as had osteoporosis and among post menopausal women, 22.5% had normal BMD, 55% had osteopenia and 22.5% were identified as having osteoporosis. According to BMI, 50% of women were normal, 42.5% were overweight and 7.5% were obese in the pre menopausal group and among post menopausal women, 20% were normal, 42.5% were overweight and 37.5% were categorized as obese. Significant differences were observed in the weight, height, waist hip circumference, BMI, body fat, metabolic age, visceral fat among women of both groups and measurements of post menopausal women were on higher side. Parameters like weight (-0.299), waist circumference (-0.283), hip circumference (-0.282) and BMI (-0.393), fat percent (-0.287), fat mass (-0.306), metabolic age (-0.379), visceral fat (-0.399) and degree of obesity (-0.398) showed overall negative correlation with BMD.

Key Words: Over weight, obesity, BMD, osteopenia, Oosteoporosis

Osteoporosis and obesity are two major public health concern complex diseases which have multifactorial etiologies. Osteoporosis or porous bones is a disease characterized by low bone mass and structural deterioration of bone tissue leading to bone fragility and an increased susceptibility to fractures of hip, spine and wrist. Operationally osteoporosis can be defined as a BMD that lies 2.5 standard deviations or more below the average value for young healthy women (WHO, 1994). The world wide pervasiveness of osteoporosis is 1 in 3 women over 50 years of age will suffer a fracture due to osteoporosis and this will amplify to 1 in 2 over 60 years of age (IOF, 2004). It is often associated with menopause (non modifiable) which is a reproductive milestone in a woman's life and is characterized by permanent end of menstruation and fertility. Obesity is defined as abnormal or extensive fat accumulation that negatively affects health. Similarities between obesity and osteoporosis like genetic and environmental effect, association of age with high incidence of osteoporosis and bone marrow adiposity and the both cells, adipocytes and osteoblasts have common progenitor—the mesenchymal stem cell. These similarities suggest some type of patho-physiologic linkage between the two diseases (Rosen and Bouxsein, 2006). However, the effect of overweight and obesity on bone and osteoporosis is still unclear in case of menopausal status of women as some researchers have shown a positive effect of high body weight (BMI) on BMD (Morin and Leslie, 2009), while according to others high BMI possess negative effect on BMD (Pirro et al., 2010). In the present study, we investigated the effect of weight, BMI, fat mass, visceral fat etc on BMD in pre and post menopausal women as this specific work has not been done yet.

MATERIAL AND METHODS

Women who participated in the Bone Mineral Density Check up Camps (January, 2012) organized by various pharmaceutical companies in Ludhiana (Punjab) were randomly selected and were asked about their willingness to participate. A total of 80 women who showed interest were selected and were divided into two groups on the basis of their menopausal status. Those who were having normal and regular periods were categorized as pre-menopausal group (Group I) and those who had attained menopause for the past one year were under post-menopausal group (Group II).

Bone Mineral Density: Bone Mineral Density of the subjects was examined by machine known as Bone Ultrasonometer whose performance correlates well with DEXA in predicting osteoporotic fractures (Holi and Radhakrishnan, 2004). The T-score is the relevant measure when screening for osteoporosis. It is the number of standard deviations above or below the mean for a healthy 30 year old adult of the same sex and ethnicity as the patient. In bone ultrasonometer the value of the density comes in form of T-score on the display screen. T score up to -1 indicate normal BMD, T score between -1 to -2.4 indicate osteopenia where as T score below -2.5 means

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osteoporosis.

Body composition and anthropometry: Body composition was assessed by a technique known as Bioelectrical Impedance using TANITA Body Composition Analyzer BC-420MA. Height was measured to the nearest 0.5 cm using an anthropometric rod and BMI was calculated using the standard formula. Waist circumference was measured at the top of upper iliac crest to the nearest 0.25cm and hip circumference was measured around the broadest circumference of the hip above the gluteal fold to the nearest 0.25 cm using a non stretch flexible measuring tape and ratio was also calculated.

The descriptive data for numerical variables are expressed as mean ± SD. Student T test was used to determine statistical differences among the two groups. Pearson correlation coefficient was used to establish correlation of BMD with various variables. The results were analyzed at 5 and 1% level of significance.

RESULTS AND DISCUSSION

The mean age of the women of Group I (pre menopause) came to 41.6 years, whereas 53.6 years were the mean age of Group II (post-menopause) subjects. For Group II subjects, the mean menopausal age was 48.36 years out of which 82.5% women had normal menopause and 17.5 % women have undergone hysterectomy. Figure 1 represents the distribution of the subjects according to the BMD (T scores as prescribed by WHO). In the pre-menopausal group, 57.5% women were normal, 40% had osteopenia and 2.5% were categorized as osteoporotic. While in the post-menopausal group, only 22.5% of the women had normal BMD, 55% were under osteopenia stage and 22.5% were osteoporotic. Thus, the incidence of osteopenia was high in both groups but osteoporosis was more in post-menopausal group.

The data of the anthropometric measurements revealed the existence of significant difference in the weight, height, waist and hip circumference and BMI among the women of both the groups. According to WHO (2004) classification of BMI, 42.5% of the women from pre-menopause group were overweight and 7.5% were obese. However, from the post-menopausal group 42.5% women were overweight but 37.5% of women were in the obese category (Figure 2). In case of Waist Hip Ratio, 65% of women from pre-menopausal group and 75% from post-menopausal group were at the risk of central obesity. Thus obesity was more common among post-menopausal women. In case of body composition parameters, significant difference in fat mass, total body water, metabolic age, visceral fat and degree of obesity was observed in the women of both the groups. Fat mass and fat mass per cent was significantly higher in post-menopausal women as compared to pre-menopausal women but significant difference was observed in the fat free mass and bone mass

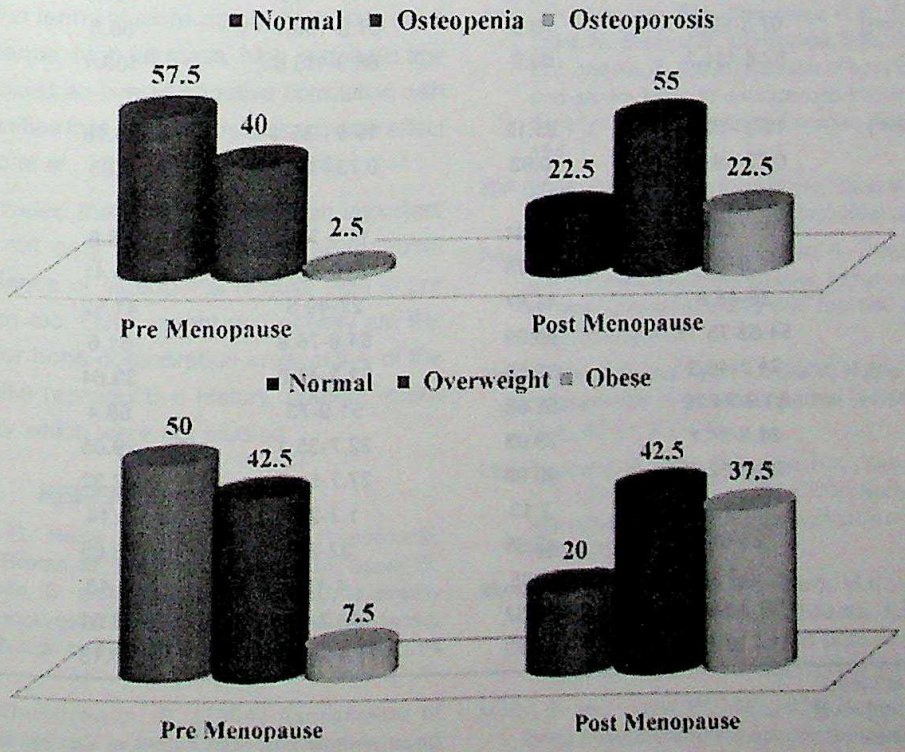


Fig.1. Distribution of the subjects according to BMD and BMI (percent)

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of both groups. Visceral fat rating and degree of obesity was much high in post-menopausal women (Table 1).

The distribution (Table 2) of subjects on the basis of BMI and BMD showed that among pre-menopausal women having osteopenia, 25% were overweight and only 2.5% were obese. However, in case of post-menopausal women having osteopenia, 30% were overweight and 15% were obese which is quite high as compared to pre-menopausal women. The categorization of post-menopausal women having osteoporosis states that 7.5% were overweight and as much as 12.5% women were obese, which clearly defines obesity as a major risk factor for osteoporosis.

The Pearson correlation coefficient analysis revealed a significant overall correlation ($p \leq 0.05$) of BMD with weight (-0.299), waist circumference (-0.283), hip circumference (-0.282) and significant overall correlation ($p \leq 0.01$) of BMD with BMI (-0.393), fat per cent (-0.287), fat mass (-0.306), metabolic age (-0.379), visceral fat (-0.399) and degree of obesity (-0.398) (Table 3).

According to the present study, osteopenia was prevalent in pre-menopausal women while both osteopenia and osteoporosis was high in post-menopausal women. Thus, indicating that menopausal status and age are correlated with BMD as also observed by earlier workers (Kadam *et al.*, 2010; Marwaha *et al.*, 2011). The results showed that the incidence of obesity in terms of BMI, waist and hip circumference was higher in post-menopausal women as compared to pre-menopausal women. According to the body composition parameters, higher per cent of fat and lower per cent of muscle mass and total body water was observed in post-menopausal women as compared to pre menopausal women. Consistent with our findings, many studies have also shown that the body composition of women changes with menopausal status leading to higher fat and lower muscle mass (Kim *et al.*, 2008). Also, fat free mass (lean mass) showed no significance with BMD as the difference between the fat free mass of the women of both the groups was negligible. The effect of body weight on bone density is attributable to both lean tissue mass and fat mass, but fat mass is the stronger and more consistent predictor of bone density in postmenopausal women (Stewart *et al.*, 2002). However, several studies implies that lean mass is of greater

Table 1. Anthropometric parameters of pre and post-menopausal women

Parameters	Pre-menopause Group – I (n = 40)		Post-menopause Group – II (n = 40)		t-value
	Range	Mean	Range	Mean	
Weight (kg)	46.1 - 84.2	63.63	48 – 84	68.57	2.64**
Height (cm)	150 – 170	158.85	141 - 166	155.9	2.8**
Waist circumference (cm)	67.3-99.1	79.8	67.3-106.7	86.5	4.13**
Hip circumference (cm	82.6-111.7	95.9	88.9-115.6	103.1	4.29**
Derived					
Body Mass Index, (kg/m²)	19.2 - 32.6	25.12	19.5 - 35.4	28.18	4.28**
Waist Hip Ratio	0.73 - 0.92	0.83	0.73 - 0.93	0.83	1.17ns
Body composition					
Fat mass (kg)	10.1-38.2	21.81	11.3-38.2	26.8	3.64**
Fat mass (%)	21.9-45.4	33.78	23.2-45.4	38.41	4.41**
Fat free mass (kg)	36-48.8	41.67	27-49.5	41.52	0.8ns
Fat free mass (%)	54.63-78.11	65.99	54.6-76.8	61.6	4.21ns
Muscle mass (kg)	34.2-46.3	39.58	32.2-47.0	39.64	0.73ns
Muscle mass (%)	51.9-74.19	62.68	51.9-73	58.4	1.42ns
Total body water (kg)	24.3-34.7	29.03	22.7-35.1	29.05	0.70ns
Total body water (%)	38.8-52.7	45.99	27.7-51.7	42.32	5.11**
Bone mass (kg)	1.8-2.5	2.13	1.7-2.5	2.14	0.81ns
Metabolic age (years)	26-66	43.68	32-74	58.05	5.59**
Visceral fat (%)	2-10	5.65	4-12	8.48	6.51**
Ideal body weight (kg)	50.2-64.8	55.57	43.7-60	53.51	2.79**
Degree of obesity	-11.7 to 48.4	14.73	-11.4 to 60.8	28.13	4.18**

* Significant at 5 per cent level
** Significant at 1 per cent level
ns=Non significant

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Table 2. Classification of selected pre and post menopausal subjects on the basis of BMD and BMI

BMI	Normal		Osteopenia		Osteoporosis	
	Pre menopause [Group I]	Post menopause [Group II]	Pre menopause [Group I]	Post menopause [Group II]	Pre menopause [Group I]	Post menopause [Group II]
Underweight (<18.5)	-	-	-	-	-	-
Normal(18.5-24.99)	6 (15)	3 (7.5)	9 (22.5)	4 (10)	1 (2.5)	1 (2.5)
Overweight(e"25)	11 (27.5)	2 (5.0)	10 (25)	12 (30)	-	3 (7.5)
Obese(e"30)	2 (5)	4 (10)	1 (2.5)	6 (15)	-	5 (12.5)

- None of the subject was underweight

Figures in parenthesis are percentages

Table 3. Correlation of BMD with anthropometric and body composition parameters

Parameters	Pre menopause Group I	Post menopause Group II	Overall
Weight	0.116 ns	-0.146 ns	-0.299*
BMI	0.19 ns	-0.254 ns	-0.393**
Waist circymference	0.083 ns	-0.272 ns	-0.283*
Hip circymference	0.044 ns	-0.221 ns	-0.282*
Waist Hip Ratio	0.06 ns	-0.133 ns	-0.064 ns
Fat percent	0.112 ns	-0.135 ns	-0.287**
Fat mass	0.118 ns	-0.158 ns	-0.306**
Metabolic age	0.039 ns	-0.209 ns	-0.379**
Visceral fat	0.091 ns	-0.261*	-0.399**
Degree of obesity	0.135 ns	-0.255 ns	-0.398**

* Significant at 5 percent level; ** Significant at 1 percent level

ns Non significant

importance for the BMD as compared to fat mass (Lim et al., 2004). Obesity in terms of more weight, high BMI, more waist hip circumference, high fat mass, high metabolic age and visceral fat showed an overall negative correlation with the BMD, which signifies that obesity possess adverse effect on the BMD (Greco *et al.*, 2010; Hsu *et al.*, 2006).

It can be concluded that osteoporosis is an important medical problem not only related to post menopausal women as its incidence of osteopenia is quite high in pre menopausal women too. Over weight and obesity are the major risk factors for bone deterioration irrespective of the other risk factors like reproductive history, nutrient intake and physical activity which were not studied.

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Assessment of Snails and Slugs Damage to Ornamental Plants, Fodder and Vegetable Crops

H. Kaur and S. Panjgotra

Department of Zoology, Punjab Agricultural University,Ludhiana – 141004, India
E-mail: harjitdhaliwal@pau.edu

Abstract: To assess gastropod damage, two commercial nurseries viz. Om and Bhola and their adjoining vegetable/fodder fields at Jalandhar, Punjab were surveyed. Study revealed that three colour forms of slugs belonging to two species, *Filicaulis alte* Ferussac and *Laevicaulis alte* Ferussac were infestating plant saplings in nurseries and fields. Two snail species *Macrochlamys indica* GA and *Macrochlamys glauca* Hutton were infestating plant saplings only in nurseries. Only one type of damage was noticed i.e. holes within the leaves of plants. Highest mean per cent plants attacked by snails and slugs were 61.1 of *Dahlia*, 57.9 of *Kalanchoe*, 57.3 of *Croton*, 54.6 of *Dieffenbachia*, 51.5 of *Dracaena* (Green), 44.4 of *Bougainvillea*, 34.2 of *Hibiscus rosasinensis*, 25.5 of *Syngonium podophyllum*, 21.5 of *Pothos scindapsus* in July. In plant nurseries, variation in damage to saplings was more consistent with variation in snail density as compared to slug density throughout the year. In fields adjoining to nurseries highest mean per cent plants of vegetable/fodder crops attacked by slugs were 43.2 of *Solanum melongena*, 41.8 of *Abelmoshus esculentus*, 53.6 of *Trifolium alexandrinum* at 4-leaf stage and 37.5 of *Zea mays* at 2-leaf stage in May. Hence gastropod control measures should be adopted in April-May and July-August.

Key Words: Fodder crop fields, plant nurseries, vegetable crop fields, snail and slug damage.

Slugs and snails are important molluscan pests of a wide range of ornamental and vegetable plants in permanently moist regions or in rainy months. The animals mostly feed on foliage during night hours and early morning and migrate during the day time under the debris, soil cracks and grasses. Seedlings of many vegetables and flowers are favoured food and high population of slugs can cause difficulties in establishing crop. Slugs completely feed on small leaves while mature leaves show holes on them or eaten away around the edge. Thicker leaves are mostly rasped on the lower surface (Jagtap 2000).

Damage caused by snails depends not only on their activity and population density, but also on their feeding habits, which differ from one species to another. In addition, during movement snails and slugs cause an undesirable smell which prevents men and even animals from feeding on these contaminated plants. Crops contaminated by snail slime, lose their marketability and hence their export potential in many countries (Baker 1989). Land snails and slugs also cause a heavy damage to seed of oil plants and leaves of ornamental plants, as well as, citrus, peach, palm and vegetables, i.e. cabbage, carrot and bean (Shoieb 2008). Hence, present studies were undertaken to study nature and extent of damage to ornamental plant saplings in plant nurseries and to vegetable/fodder crop fields in the vicinity of plant nurseries.

MATERIAL AND METHODS

Selected nurseries viz., Om nursery and Bhola nursery at Jalandhar, were surveyed to study the nature and extent of damage inflicted by snails, *M. indica, M. gluaca* and slug, *F. alte* to plant saplings (three replicates, each 10 m² size for each nursery plant were taken) at fortnightly interval throughout the year. Vegetable/fodder fields in vicinity of ornamental plant nurseries were surveyed and plants were observed carefully for slug damage at fortnightly intervals throughout crop period (three replicates, each of half acre for each vegetable and fodder crops were taken). Total plants in rows along with damaged ones were counted in each replicate. Each type of damage was recorded. In case of berseem, total plants per m² area (6 spots per replicate) along with damaged ones were counted. Plants were observed at fortnightly intervals.

RESULTS AND DISCUSSION

Results of assessment of damage inflicted by snails and slugs to plants in two nurseries *viz.*, Bhola nursery and Om nursery and their adjoining vegetable and fodder crop fields at Jalandhar are presented in Table 1, 2, 3 and 4, respectively. Gastropods carved irregular holes within the leaves from April-October as animals were in hibernation from November to February.

Damage to Ornamental Plants

Dieffenbachia *(Dieffenbachia)*: In Om plant nursery no damage was seen in March and first week of April. Mean per cent damage was maximum on 10th July i.e. 41.1 (Table 1) with increase in snail and slug population density i.e. 1.15 snails per m² and 0.65 slugs per m² (Fig 1). Then damage decreased in the preceding months and no

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Table 1. Per cent ornamental plants damaged by snail, *Macrochlamys indica* and slug, *Filicaulis alte* per replicate/row at Om nursery, Jalandhar

Dates/Year 2011	*Dieffenbachia*	*Dracaena sanderiana*	*Codiaeum varigatum pictum*	*Hibiscus Rosa sinensis*	*Pothos scindapsus*	*Kalanchoe sect. bryophyllum*
20-Mar	-	-	-	-	-	-
03-Apr	-	7.1 ± 0.36	-	-	-	-
17-Apr	6.74 ± 0.64	14.3 ± 0.72	6.5 ± 0.45	-	-	7.3 ± 0.61
01-May	11.8 ± 2.27	18.7 ± 0.83	9.1 ± 1.81	6.8 ± 0.52	-	14.3 ± 0.72
15-May	24.1 ± 1.91	23.3 ± 2.35	16.9 ± 2.39	13.3 ± 0.63	6.6 ±0.31	18.9 ± 0.65
29-May	26.2 ± 4.37	30.2 ± 2.37	23.3 ± 0.18	-	6.2 ± 0.27	37.1 ± 1.84
12-Jun	28.2 ± 1.56	34.2 ± 3.61	33.7 ± 3.21	22.1 ± 1.82	14.3 ± 0.72	45.2 ± 1.46
26-Jun	35.7 ± 3.28	46.8 ± 2.21	48.1 ± 4.21	26.4 ± 3.33	21.5 ± 1.08	57.9 ± 4.01
10-Jul	41.1 ± 3.22	57.7 ± 1.38	22.6 ± 2.48	24.5 ± 2.08	17.4 ± 1.27	37.2 ± 0.98
24-Jul	32.7 ± 2.91	53.4 ± 4.57	14.2 ± 3.29	17.9 ± 2.52	9.7 ± 1.74	25.5 ± 2.61
07-Aug	20.1 ± 1.43	39.3 ± 3.71	6.19 ± 0.59	9.5 ± 1.91	8.3 ± 0.49	23.4 ± 3.48
21-Aug	8.8 ± 0.31	30.4 ± 2.15	-	-	-	-
04-Sep	-	26.9 ± 5.79	-	-	-	-
18-Sep	-	20.2 ± 4.39	-	-	-	-
02-Oct	-	11.6 ± 4.02	-	-	-	28.6 ± 1.45
16-Oct	-	7.5 ± 1.13	-	-	-	-
30-Oct	-	-	-	-	-	-

Values are Mean±SE

damage found after 21st August. In Bhola nursery, mean per cent damage was very less in the last week of March (8.8%) and infestation increased afterwards. Maximum mean per cent damage was seen on 3rd July i.e. 54.6 (Table 2), when overall population density was maximum (2.25 snails per m^2 and 0.5 slugs per m^2. Infestation of plants then decreased up to mid of August and no damage was seen afterwards (Fig 2).

In earlier studies, same type of damage to *Dieffenbachia* was observed in three plant nurseries at Ludhiana (Suman, Bengal and Carewell nurseries and flowers). More damage was in April and September (Kaur and Chhabra 2011).

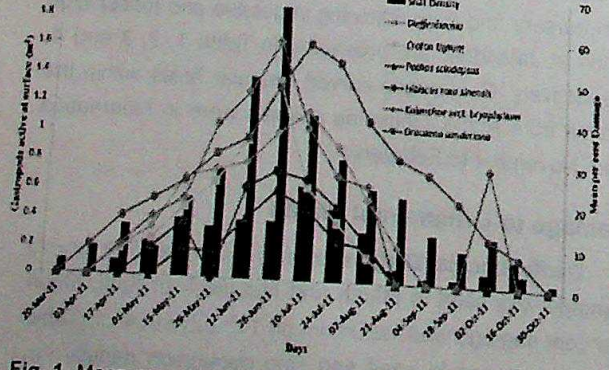


Fig. 1. Mean per cent plants damaged by snail, *M. indica* and slug, *F. alte* of various ornamental plants in Om nursery at Jalandhar

Dracaena *(Dracaena sanderiana)*: In both nurseries no damage was seen in the month of March. In Om plant nursery,damage observed from 3rd April to 16th October and was maximum on 10th July (Table 1), when overall snail and slug population increased to 1.15 snails per m^2 and 0.65.2 slugs per m^2 (Fig 1).

In Bhola plant nursery, no damage on *Dracaena* green was observed till second week of April. Mean per cent damage was maximum on 3rd July i.e. 51.5 (Table 2), due to increase in surface active gastropod population (Fig 2). Damage decreased afterwards as the surface active snail and slug population decreased and no damage was seen after October.

Croton *(Codiaeum variegatum pictum)*: In both plant nurseries, no damage occurred in March and first week of April. It started mid-April onwards. In Om plant nursery, damage was maximum on 26th June i.e. 48.1 per cent when overall population density of snails was maximum i.e. 1.9 snails per m^2 and 0.4 slugs per m^2 (Fig 1). Infestation decreased afterwards and was minimum on 7th August i.e. 6.19 (Table 1) when overall population density of snails and slugs also decreased to 0.65 snails per m^2 and 0.35 slugs per m^2 (Fig 1). No damage occurred after first week of August. In Bhola nursery, damage was maximum as recorded on 3rd July i.e. 57.3 (Table 2, Fig 2). Then infestation decreased afterwards. No damage was visible in August to first week of October. Damage was found again in October and none afterwards.

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Table 2. Per cent ornamental plants damaged by snails, *Macrochlamys indica, Macrochlamys glauca* and slug, *Filicaulis alte* per replicate at Bhola nursery, Jalandhar and berseem plants by slug, *Flicaulis alte* in the adjoining field

Dates (year 2011)	*Dieffenbachia*	*Dracaena sanderiana*	*Codiaeum varigatum pictum*	*Hibiscus rosa sinensis*	*Syngonium podophyllum*	*Bougainvillea sp.*	*Dahlia imperlias*	Berseem (*Trifolium alexandrinum*)
27-Mar	8.8 ± 3.36	-	-	-	-	-	-	-
10-Apr	11.1 ± 3.41	-	-	-	-	-	-	13.1 ± 0.44*
24-Apr	12.3 ± 4.77	11.8 ± 2.27	12.3 ± 3.78	-	-	-	-	47.4 ± 0.88*
08-May	16.1 ± 4.38	17.9 ± 3.74	17.6 ± 3.45	-	-	16.7 ± 0.99	18.2 ± 1.18	51.1 ± 0.93**
22-May	19.6 ± 2.64	-	30.2 ± 2.14	12.3 ± 0.79	9.5 ± 1.46	21.9 ± 4.26	23.6 ± 2.24	19.8 ± 1.71**
05-Jun	26.4 ± 5.18	32.1 ± 4.04	37.1 ± 4.86	18.5 ± 2.43	13.9 ± 2.64	28.8 ± 1.24	28.9 ± 4.81	-
19-Jun	44.7 ± 7.86	28.1 ± 1.11	45.9 ± 0.28	27.1 ± 2.72	20.1 ± 5.51	38.8 ± 1.88	38.2 ± 5.19	-
03-Jul	54.6 ± 0.60	51.5 ± 3.71	57.3 ± 3.86	34.2 ± 3.61	25.5 ± 2.06	44.4 ± 1.77	42.1 ± 2.73	-
17-Jul	26.3 ± 7.43	35.1 ± 2.81	51.5 ± 3.71	26.1 ± 1.97	12.9 ± 2.37	38.8 ± 1.88	50.2 ± 2.97	20.7 ± 1.39*
31-Jul	18.1 ± 3.44	32.3 ± 3.27	40.3 ± 3.64	21.5 ± 1.08	8.3 ± 0.49	31.2 ± 2.99	61.1 ± 1.88	34.6 ± 1.94**
14-Aug	10.0 ± 3.25	22.5 ± 3.22	-	15.9 ± 1.42	6.74 ± 0.64	24.6 ± 4.01	41.8 ± 2.47	30.5 ± 2.48**
28-Aug	-	-	-	7.7 ± 0.42	-	-	-	15.2 ± 0.81***
11-Sep	-	28.4 ± 1.42	-	-	-	-	-	-
25-Sep	-	20.1 ± 1.43	-	-	-	19.3 ± 2.36	34.5 ± 4.63	-
09-Oct	-	20.2 ± 4.39	27.1 ± 2.72	-	-	14.2 ± 3.29	20.4 ± 1.74	-
23-Oct	-	18.5 ± 2.43	14.5 ± 2.51	-	-	-	-	-
06-Nov	-	-	-	-	-	-	-	-

Values are Mean±SE

Damage to * 2-leaf stage, ** 4-leaf stage, *** 6-leaf stage.

China rose (*Hibiscus rosa sinensis*): No damage was visible during March-April in both plant nurseries due to very low surface active population density of snails and slugs. In Om nursery, mean per cent damage was maximum on 26th June and no damage found after 7th August (Table 1, Fig 1). In Bhola nursery, mean per cent damage was 12.3 on 22nd May. Infestation increased afterwards. Highest mean per cent damage was 34.2 during first week of July (Table 2, Fig 2). More damage to *Hibiscus* occured in mid-June to mid-July in both nurseries at Jalandhar.

Money plant (*Pothos scindapsus*): In Om nursery, no damage to plants was visible from March till mid-May. Damage in the form of irregular holes within and margins of leaves was recorded on 15th May i.e. 6.6. Infestation increased afterwards and was maximum on per cent 26th June i.e. mean per cent damage was 21.5 (Fig 1). Afterwards damage decreased to 8.3 during first week of August and no damage was visible after last week of August. So, more damage to Money plant occurred in June and July (Table 1).

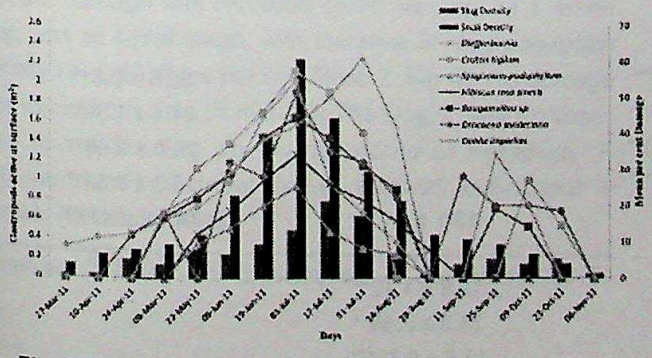


Fig. 2. Mean per cent plants damaged by snail, *M. indica* and slug, *F. alte* of various ornamental plants in Bhola nursery at Jalandhar

Pathar chat (*Kalanchoe sect. bryophyllum*): In Om nursery, the molluscs started damage from mid-April onwards which increased in the preceding months and was highest on 26th June, i.e. 57.9 (Table 1, Fig 1). No damage was visible from mid-August till September. Again, 28.6 damage was recorded on 2nd October, when overall snail and slug population was 0.35 snails per m² and 0.1 slugs per m² (Fig 1).

***Syngonium podophyllum*:** In Bhola nursery, no damage was observed from March to mid-May. Highest mean per cent damage to plants was recorded on 3rd July i.e. 25.5. Damage decreased afterwards and was lowest on 14th August i.e. 6.74 and no damage was visible afterwards (Table 2, Fig 2).

Bougainvillea (*Bougainvillea sp*): In Bhola nursery, maximum mean per cent damage was recorded during first week of July i.e. 44.4 (Table 2). Damage decreased afterwards. No damage was visible from mid-August to mid-September. Again damage was recorded on 25th September (19.3 per cent). Leaves were destroyed heavily.

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Dahlia (*Dahlia imperlias*): In Bhola nursery, maximum mean percent damage to *Dahlia* was 61.1 on 31st July, when overall active snail and slug population was 1.1 snails per m² and 0.65 slugs per m² (Fig 2). Infestation decreased afterwards till 14th August. No damage was visible from mid-August to mid-September. Damage was again seen to be 34.5 as recorded on 25th September. No damage was found after first week of October (Table 2). In earlier studies, highest damage to *Dahlia* plants by snails and slugs was 52.5% in July, 2010 in New Indian plant nursery, Dhuri (Kaur 2011).

The order of preference of ornamental plants by snails and slugs in Om nursery was *Kalanchoe sect. bryophyllum> Dracaena sanderiana> Croton tiglium> Dieffenbachia > Hibiscus rosa sinensis>Pothos sciendapsus.*

The order of preference of ornamental plants by snails and slugs in Bhola nursery was *Dhalia imperlias> Croton tiglium> Dieffenbachia > Dracaena sanderiana> Hibiscus rosa sinensis> Syngonium podophyllum.*

In plant nurseries, variation in damage to plant saplings was more consistent with variation in snail population density as compared to that of slugs throughout the year i.e. snails caused more damage to plant saplings than slugs (Fig 1 and 2). Moreover, damage to plant saplings was high corresponding to more snail and slug population density in Bhola nursery as compared to that in Om nursery. The damage to most of the plants was more from mid-May to first week of August in Om nursery and in June-July in Bhola nursery. It is suggested that slug and snail control measures should be adopted from June-July in plant nurseries.

Damage to crop plants in field adjoining plant nurseries

1. Vegetable crops in the field adjoining Om nursery

Brinjal (*Solanum melongena*): The slug damage was in the form of irregular holes in the leaves only. Damage was maximum on 15th May i.e. 43.2 per cent on 4-leaf stage of crop, when overall slug population increased to 0.35 slugs per m² (Fig 3). Afterwards damage decreased from July onwards with decrease in slug population in field and no damage was found in September as crop matured (Table 3).

In earlier studies, the leaf damage at 4-leaf stage was more pronounced (51%) by the slug, *F. alte* ; debarked stems (13.32%) and consumed leaf margins (13.33%) of 6-leaf brinjal saplings in laboratory feeding test (Kaur and Kaur 2003).

Lady's finger (*Abelmoshus esculentus*): Slugs excavated holes within leaves. Highest mean per cent damage was caused to 4-leaf stage of crop as recorded on 15th May i.e. 41.8 (Table 3, Fig 3). No damage was found in the month of June as no slug was trapped from the field in

Table 3. Per cent vegetable and fodder crop plants damaged by snail, *Macrochlamys indica* and slug, *Filicaulis alte* per replicate/row at field adjoining to Om Nursery at Jalandhar.

Dates\ year 2011	Brinjal *(Solanum melongena)*	Ladies finger *(Abelmoshus esculentus)*	Maize *(Zea mays)*	Berseem *(Trifolium alexandrinum)*
20-Mar	-	-	-	-
03-Apr	13.6 ± 0.72*	-	-	-
17-Apr	25.2 ± 2.25**	28.1 ± 1.11*	14.5 ± 2.54*	37.1 ± 1.57*
01-May	34.7 ± 1.70**	32.3 ± 2.45*	26.1 ± 2.37*	43.6 ± 1.11**
15-May	43.2 ± 2.05**	41.8 ± 2.47**	37.5 ± 1.48*	53.6 ± 1.92**
29-May	34.7 ± 1.71***	32.4 ± 1.04**	25.7 ± 2.78**	44.9 ± 0.23***
12-Jun	-	-	-	-
26-Jun	-	-	-	-
10-Jul	29.1 ± 0.58****	17.6 ± 0.61***	-	25.6 ± 0.81*
24-Jul	25.2 ± 2.25****	24.1 ± 2.63***	-	24.1 ± 1.39**
07-Aug	12.6 ± 1.12****	17.6 ± 0.61****	-	20.6 ± 2.08**
21-Aug	-	11.8 ± 2.27****	-	15.3 ± 0.69**
04-Sep	-	-	13.1 ± 0.72*	34.1 ± 2.37***
18-Sep	-	-	-	30.9 ± 1.36***
02-Oct	-	-	12.6 ± 1.12**	-
16-Oct	-	-	24.3 ± 2.59**	-
30-Oct	-	-	13.6 ± 0.72***	-

Values are Means±SE

*Damage to * 2-leaf stage, ** 4-leaf stage, *** 6-leaf stage, **** 8-leaf stage.*

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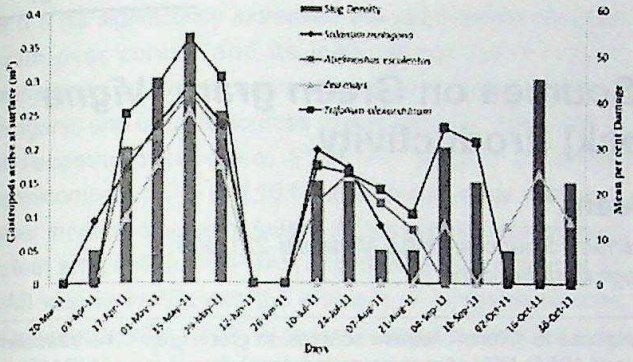


Fig. 3. Mean per cent plants damaged by snail, *M. indica* and slug, *F. alte* of various vegetable crops in field adjoining Om nursery at Jalandhar

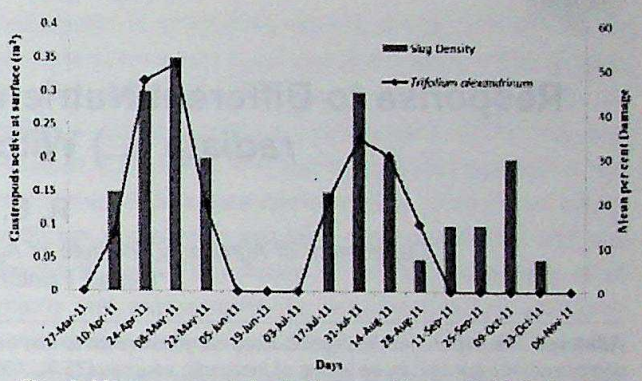


Fig. 4. Mean per cent plants damaged by snail, *M. indica* and slug, *F. alte* of Berseem crops in field adjoining Bhola nursery at Jalandhar

this month. Damage decreased afterwards and was minimum in last week of August i.e. 11.8 to 8-leaf stage of plant, when number of slugs also decreased to 0.05 slugs per m² (Table 3, Fig 3).

2. **Fodder Crops**

In the field adjoining Om nursery

Maize (*Zea mays*): Slug damage was in the form of holes within the leaves. Highest mean per cent damage was caused to 2-leaf stage of crop on 15th May i.e. 37.5 (Table 3, Fig 3). No damage was seen from June to August. Again damage was seen on 4th September to 2-leaf stage of crop to be 13.1, when overall slug population was 0.2 slugs per m² (Table 3, Fig 3). No damage was visible after October.

Berseem (*Trifolium alexandrinum*): Slugs excavated irregular holes in the leaves. In the field adjoining Om nursery, highest damage was caused to 4-leaf stage of crop as recorded on 15th May i.e. 53.6,when overall slug population increased to 0.35 slugs per m² (Table 3, Fig 3). Mean per cent damage decreased afterwards and no damage was visible after September, as the number of slugs decreased in the field.

In the field adjoining Bhola nursery, highest mean percent damage was recorded on 8th May i.e. 51.1, when crop was at 4-leaf stage, with increase in slug population density i.e. 0.35 slugs per m² (Table 2, Fig 4). No damage was found from June till mid-July.The slug, *L. alte* Ferussac was found feeding on young plants of berseem, *T. alexandrinum* in October during 1994-95 at Bhogpur in Punjab (Dhaliwal 1998).

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The study thus revealed that the incidence of slug damage increased with increased activity of slugs in the field, which in turn depend on the presence of soil moisture content in crop ecosystem. In general, young seedling stage of crop was more vulnerable to slug attack but sometimes even the older plants were also attacked. More damage was observed in April-May and July-August in both the vegetable/fodder fields adjoining to nurseries. So, slug control measures must be adopted during these months.

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Indian Journal of Ecology

Response to Different Nutrient Sources on Green gram [*Vigna radiata* (L.) Wilczeck] Productivity

R. S. Meena*

Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi-221 005
**E-mail: rsmeenaagro@gmail.com*

Abstract: The experiment was conducted on green gram to find out response to different nutrient sources on green gram .The treatments comprised one control, three levels of inorganic sources (75 %, 100 % and 125 % NPK of recommended dose), four levels of FYM (5t/ ha, 10t/ ha, 15t/ ha and 20t /ha) and four levels of vermicompost (2.5 t/ ha, 5 t /ha, 7.5 t /ha and 10 t /ha). Application of NPK at 100 % recommended dose, FYM at 10 t/ ha and vermicompost at 5 t/ ha significantly increased the number of pods per plant, number of seeds per pod, test weight, seed yield, straw yield, biological yield, harvest index and nutrient uptake of green gram over control as well as over lower levels of inorganic and organic sources of nutrients.

Key words: FYM, Green gram, Nutrient uptake, Vermicompost

Green gram (*Vigna radiata* (L.) Wilczeck) is an important pulse crop among the grain legumes grown in India. Every 100 g of edible portion of green gram seed contains 75 mg calcium, 4.5 mg phosphorus, 24.5 g protein and 348 Kcal. energy. Thus, increase in production of this crop can meet the expectations of the food policy makers and nutrition planners (Kramany *et al.*, 2001). Being a legume crop, green gram fixes 30-40 kg nitrogen /ha in a short duration (60-65 days) and is also suited to light textured soils of western Rajasthan. The average productivity of green gram is very low in Rajasthan. One of the reason is that the crop is grown on poor fertility soils. The problem is compounded by the fact that majority of farmers in rainfed area are resource poor with low risk bearing capacity and generally do not apply recommended dose of fertilizer either through organic and inorganic sources. Looking into these facts, increasing awareness about nutrition of green gram requires adequates attention. Crop response to pure organic manuring (FYM/Vermicompost) and the extent of response depends on several factors such as degree of humification and its C/N ratio, soil characteristics, moisture regimes of soil during the growth of the crop, time and method of application (Jain *et al.*, 1996).

Vermicompost not only increases organic carbon status of the soils but also increases the soil water holding capacity, flocculation of soil and availability of all micro and macronutrients, thus making the soil and crop production sustainable one (Rajkhowa *et al.*, 2000). FYM, besides being a rich source of micronutrients, also helps in improving physical condition of the soil and yield of the crop. Hence, the present investigation was undertaken to find out the effect of organic and inorganic sources of nutrients on yield attributes, yield and economics of green gram in arid western Rajasthan.

MATERIAL AND METHODS

The experiment was conducted at Agronomy farm College of Agriculture, RAU Bikaner during *Kharif* season of 2004-2005. The soil of the experimental field was loamy sand and low in organic matter. The soil pH was 8.2. It was low in organic carbon (0.09 %), available nitrogen (80.54 kg/ha) and medium in available phosphorus (18.80 kg/ ha) and potassium (198.00 kg /ha). The treatments comprised one control, three levels of inorganic sources (75 %, 100 % and 125 % NPK of recommended dose), four levels of FYM (5t /ha, 10t /ha, 15t /ha and 20t /ha) and four levels of vermicompost (2.5 t/ ha, 5 t /ha, 7.5 t/ ha and 10 t/ ha) laid out in randomized block design with three replications. Nitrogen, phosphorus and potassium were applied as per treatments as basal dose at the time of sowing in furrows (30 cm apart) at the depth of 10 cm. Well decomposed FYM was applied as per treatment 21 days before of sowing and was thoroughly incorporated with the help of spade in 15 cm top soil layer. The calculated quantity of vermicompost as per treatment was broadcasted and thoroughly incorporated in soil with the help of spade at the time of sowing. Green gram variety RMG–62 was sown @ 15 kg / ha in line at 30 cm at a depth of 5 cm by "*Kera* method" in open furrows. Crop received 85.9 mm of rainfall in 5 rainy days in the growing season and therefore was given two irrigations through sprinkler.

RESULTS AND DISCUSSION

The data in Table 1 showed that inorganic source of nutrients as NPK 100 % of recommended dose and organic sources of nutrients like, FYM at 10 t /ha and vermicompost

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at 5 t/ ha significantly increased the plant height of green gram over control and its lower levels but it remain statistically at par to each other,. The higher levels of inorganic and organic sources of nutrients *viz.*, NPK 125 % of recommended dose, FYM 10, 15 and 20 t /ha, vermicompost 5, 7.5 and 10 t /ha remained at par with each other in increasing plant height. A perceptible improvement in leaf area index at 60 DAS and chlorophyll content at 45 DAS was observed with the increase of inorganic sources of nutrient at NPK 100 % of recommended dose, FYM at 15 t /ha and vermicompost at 5 t/ ha over control and lower levels. Application of NPK at 100 % recommended dose, FYM at 10 t /ha and vermicompost at 5 t/ ha significantly increased the number of pods per plant, number of seeds per pod and test weight over control and lower dose of FYM and vermicompost. Higher dose of organic and inorganic sources were at par with each other and with 100% NPK recommended dose, FYM at 10 t/ ha and vermicompost 5 t/ ha in LAI, chlorophyll content and yield attribute.

Data in Table 2 revealed that recommended dose of organic nutrient (NPK), 15 t FYM ha^{-1} and 5 t/ ha vermicompost application significantly increased seed, straw and harvest index of green gram over control and lower level of organic and inorganic sources of nutrients. The higher levels of NPK, FYM and vermicompost were significantly at par with each other .The increase in seed and straw yield of green gram was due to significantly higher yield attributes and growth characters like LAI and chlorophyll content in these treatments. The increased yield attributes and yield might be due the increased supply of almost all plant essential nutrients by translocation of the photosynthates accumulated under the influence of the source of organic nutrients. Further, the translocation and accumulation of photosynthates in the economic sinks resulted in increased grain and straw yields. FYM, besides the rich sources of micronutrients, also helps in improving physical condition of the soil and thereby yield of the crop (Saxena *et al.*, 2001). It is also thought that repeated use of this humus encourages earthworms in great extent and is sufficient numbers in inorganic carbon deficient arid and semi-arid soils. Flocculation of soil and availability of all micro and macronutrients, making the soil and crop production sustainable one Singh *et al.* (2005) also reported increased seed yield of the green gram by using 10 t FYM / ha as compared to control and 5 t FYM/ ha.

The Table 2 further reveled that significantly higher net return was obtained with recommended dose of fertilizer over all other treatments and it was statically at par with 125% NPK recommended doses this may due to higher cost of organic sources of nutrients (FYM and Vermicompost). The increased net returns could be explained on the basis of increased yield under the influence of sources of inorganic nutrients in the present investigation. Similar, results have been reported by Yadav *et al.* (2004).

Significantly higher N, P and K uptake by green gram was recorded in recommended dose of fertilizers, 15t FYM/ ha, 5 t /ha vermicompost treatments over control and lower doses and were statically at par with higher doses of organic and inorganic sources (Table 2) this higher due to higher dry matter (seed+ straw) obtained in these treatments which consequently increase the total uptake of nutrients. The uptake of major nutrients under inorganic sources of nutrients *viz.*, N, P and K is the function of crop yield and its content. The higher nitrogen, phosphorus and potassium content with increased seed and straw yields probably led

Table 1. Effect of different nutrient sources on plant height, leaf area index and Chlorophyll content and yield attributes of green gram.

Treatment	Plant height (cm)	Leaf area index(LAI)	Chlorophyll content(mg /g)	Number of pods/ plant	Number of seed/pod	Test weight (g)
Control	23.00	1.840	1.116	18.33	4.47	28.00
75 % NPK of RDF	27.10	2.520	1.445	22.45	5.84	31.07
100 % NPK of RDF	30.17	3.051	1.695	26.18	7.10	33.60
125 % NPK of RDF	30.33	3.125	1.794	26.64	7.27	33.75
5 t FYM /ha	26.27	2.363	1.417	21.53	5.45	30.33
10 t FYM/ ha	29.35	2.673	1.643	24.50	6.33	31.41
15 t FYM/ ha	29.47	2.813	1.719	25.50	6.48	32.00
20 t FYM /ha	29.50	2.907	1.747	26.45	6.69	32.18
2.5 t Vermicompost /ha	26.33	2.492	1.461	22.29	5.76	31.28
5 t Vermicompost /ha	29.37	2.953	1.645	25.83	6.98	
7.5 t Vermicompost/ ha	29.47	3.056	1.684	26.33	7.19	33.67
10 t Vermicompost/ ha	29.48	3.120	1.704	26.50	7.28	33.73
CD ($P = 0.05$)	2.89	0.300	0.149	2.96	0.85	1.67

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Table 2. Effect of different nutrient sources on yield, harvest index, net return and nutrient uptake of green gram

Treatment	Seed Yield (kg/ ha)	Straw Yield (kg/ ha)	Harvest index (%)	Nitrogen uptake (kg /ha)	Phosphorus uptake(kg/ ha)	Potassium uptake (kg /ha)
Control	5.72	12.85	28.94	37.45	4.78	30.41
75 % NPK of RDF	7.48	15.78	30.82	54.02	6.78	42.92
100 % NPK of RDF	8.98	18.41	31.78	69.73	8.71	55.01
125 % NPK of RDF	9.27	19.20	31.50	72.77	9.53	60.09
5 t FYM /ha	6.80	14.75	29.99	49.57	6.19	39.37
10 t FYM/ ha	7.83	16.42	30.93	58.74	7.56	47.95
15 t FYM/ ha	8.33	17.43	31.22	66.09	8.31	52.47
20 t FYM /ha	8.56	17.85	31.26	68.43	8.62	54.30
2.5 t Vermicompost /ha	7.29	15.70	30.38	53.84	6.66	42.22
5 t Vermicompost /ha	8.70	18.25	31.14	67.07	8.47	53.70
7.5 t Vermicompost/ ha	9.03	18.87	31.32	70.99	9.15	57.44
10 t Vermicompost/ ha	9.21	19.15	31.49	73.21	9.39	58.85
CD ($P = 0.05$)	0.94	1.63	1.75	5.53	0.86	5.63

to the more uptake of major nutrients by the green gram crop. Significant increase in protein, N, P and K content and uptake due to inorganic sources of nutrients under the present study are in close agreement with the findings of Kramany *et al.* (2001), Borse *et al.* (2002).

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Effect of Irrigation and Nitrogen Levels on Forage Sorghum (*Sorghum bicolor*) under Different Cutting Management

Amandeep Saini[1]* and U.S. Tiwana

Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana-141 001, India
[1]Deptt. of Physical and Environmental Sciences, University of Toronto, Canada
**E-mail: aman.saini@mail.utoronto.ca*

Sorghum (*Sorghum bicolor*) is the principal non legume fodder crop grown all over the India under poor management. As forage, it is fast growing, palatable, nutritious and utilized as silage and hay besides fresh feeding. Agronomic techniques are very helpful to obtain its higher productivity of good quality herbage to fulfill feeding requirement of dairy animals. Being an exhaustive crop, sorghum suffers heavily if proper amount of fertilizer is not applied. All the crops in general and fodders in particular, use nitrogen in large quantity as nitrogen is one of the most important factors, which influences the yield and quality of fodders. Scheduling of irrigation is very important agronomic practice particularly in case of fodders like sorghum as uptake of water is involved in solubilization and transportation of nutrient elements from soil to the plant system. For better efficiency of live stock, only quantitative production is not important, but the quality also plays its role. Therefore, harvesting stage of crop is also very important for good quality fodder as the succulency dry matter and HCN content of fodder are largely affected by harvesting stage of the crop.

The field experiment was conducted at Forage Research Farm, Department of Plant Breeding & Genetics, Punjab Agricultural University, Ludhiana. Twenty seven treatment combinations comprising three harvesting stages (50, 75 and 100 days after sowing), three irrigation scheduling (7, 14 and 21 days before harvest) and three levels of nitrogen (75, 100 and 125 per cent nitrogen of the recommended dose) were tested in slit plot design with three replications. The soil of experimental field was loamy sand in texture, low in organic carbon and available nitrogen and high in available phosphorus and potassium. The values of pH and electrical conductivity of the experimental field were 7.5 and 0.20 (dmm^{-1}) respectively. Sorghum variety HC 308 was sown in lines 22 cm apart using seed rate of 62.5 kg/ha. Full dose of 20 kg P_2O_5 /ha and half dose of nitrogen was applied at the time of sowing and remaining half of nitrogen was applied after four weeks as per treatments. HCN was determined from fresh plants samples by using the method of Hogg and Ahlgren (1942)..

Irrigation and nitrogen levels did not significantly influence the plant population of sorghum at different growth stages (Table 1). This could be due to the fact that sorghum does not have capacity to produce tillers. On the other hand, plant height increased whereas leaf stem ratio decreased with the advancement of plant age. Plant height at 100 days as to sowing (DAS) was significantly higher than at 50 DAS as the plants got sufficiently more time for their growth and development. The leaf-stem ratio was significantly highest at 50 DAS and decreased with advancement of age. Increase in stem weight due to stem elongation and increase in stem diameter is the main reason of decrease in leaf-stem ratio with advancement of harvesting age.

Plant height and leaf stem ratio were also significantly varied by scheduling of last irrigation. Both parameters decreased with delay in last irrigation. Maximum plant height (206.7 cm) and leaf stem ratio (0.75) were recorded when last irrigation was given at 7 days before harvesting as compared to last irrigation applied at 14 and 21 days before harvest. The adequate moisture content increases the cell elongation and uptake of nutrients resulting in more plant height and leaf stem ratio. Vannavong and Detpiratmongkol (2008) also reported increase in weight by relieving water stress. Significant increase in leaf-stem ratio and plant height was observed with each increment in nitrogen level up to 125 per cent nitrogen of the recommended dose. Application of 125 per cent nitrogen of the recommended dose significantly increased plant height by 17 and 5.8 % and leaf stem ratio by 46.9 and 20 % over 75 and 100 % of the recommended dose, respectively. Agrawal *et al.* (2005) also found highest leaf-stem ratio (0.59) with highest dose of nitrogen.

Harvesting stage influenced the fodder yield of sorghum significantly. Sorghum crop harvested at 100 DAS (days after sowing) produced highest green fodder and dry matter yield of 597 q ha^{-1} and 186 q ha^{-1} respectively (Table 1). Increase in fodder yield with delay in harvest stage from 50 to 100 DAS was due to more growth of yield attributing characters like plant height, stem diameter, more number

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of leaves per plant etc. Cakmakc *et al.* (1999) revealed that fresh weight of plants increased from panicle initiation stage to the hard dough stage. Increase in dry matter with the advancement of age was due to more deposition of fibrous material in plant parts. Significantly higher green fodder and dry matter yields were obtained when the crop was irrigated at 7 days before harvest. Maximum green fodder (500 q ha^{-1}) and dry matter yield (137 q ha^{-1}) was obtained with last irrigation at 7 days before harvest which was 4.8 and 17 % higher green fodder and; 14.9 and 30.7 % higher dry matty yield than last irrigation at 14 and 21 days before harvest, respectively. Irrigation contributed to increase in yield because it helps in the absorption and translocation of nutrients from the soil to the growing parts of the plants and moreover increases moisture content of plant parts.

The yield increased significantly with the increase in dose of nitrogen. The highest green fodder yield (520 q ha^{-1}) and dry matter yield (126 q ha^{-1}) was recorded with the application of 125 per cent nitrogen of the recommended dose. Significantly higher yield at highest nitrogen dose might be associated with high photosynthetic activity, vigorous growth, better plant height, higher carbohydrate utilization and increase in fodder succulence.

The HCN content was highest at 50 DAS and decreased rapidly with the advancement of crop stage upto 100 DAS (Table1). The highest HCN content observed at 50 DAS was 172.7 ppm which reduced to 88.3 ppm at 75 DAS and 42.9 ppm at 100 DAS. The corresponding values at 100 and 75 per cent of recommended dose were 107.5 and 70.1 ppm and the results were in accordance with study done by Sultan (2003). The decrease in HCN content in later stages might be due the proportional increase in weight of plant parts that contain low HCN content i.e. stem and this is confirmed by the trend in leaf-stem ratio which narrowed down as the plant advanced in age.

Water stress affected HCN content significantly. HCN content was lowest (68.2 ppm) with last irrigation at 7 days before harvest as compared to 96.2 and 139.6 ppm with last irrigation at 14 and 21 days before harvest, respectively. Irrigation affected the HCN content because of the dilution effect in plant parts. Nitrogen application influenced the HCN content in forage sorghum. With each increment in dose of nitrogen, HCN content increased up to the highest level of nitrogen with the maximum of 126.4 ppm at 125 per cent nitrogen of the recommended. HCN increased with increase in nitrogen because at higher nitrogen rates the absorption also increases in plant in the forms of nitrate. It later on get changed to hydrocyanic acid as an intermediate stage between nitrates and amino acids in the formation of proteins and this could have possibly increased HCN content. As soon as HCN is formed, it combines with glucose and benzaldehyde to form a non toxic glucoside. However, it accumulates in plant if conditions are not favourable for rapid and complete synthesis of protein. Wheeler *et al.* (1980) also found that HCN content was increased by 28 % by nitrogen fertilization.

Thus it was concluded that sorghum crop harvested at 100 DAS (days after sowing) produced highest green fodder

Table 1. Effect of harvesting stage, time of last irrigation and nitrogen on growth parameters, yield and HCN content

Treatments	Plant population (per m row length)	Plant height (cm)	Leaf -stem ratio	Green fodder yield (qha^{-1})	Dry matter yield (qha^{-1})	HCN content (ppm)
Harvesting stage						
50 DAS	15	117.5	0.93	317	49.7	172.7
75 DAS	15	206.9	0.49	491	122	88.3
100 DAS	15	255.6	0.38	597	186	42.9
CD (p = 0.05)	NS	6.2	0.03	27.7	9.7	1.2
Last Irrigation						
7 days before harvest	14	206.7	0.74	500	136	68.2
14 days before harvest	15	192.2	0.57	477	118	96.2
21 days before harvest	15	181.2	0.50	427	104	139.6
CD (p = 0.05)	NS	6.2	0.03	27.7	9.7	1.2
Nitrogen levels						
75% of the recommended	15	177.1	0.49	409	111	70.1
100% of the recommended	16	195.7	0.60	476	120	107.5
125% of the recommended	15	207.2	0.72	520	126	126.4
CD (p = 0.05)	NS	2.8	0.009	8.4	2.1	0.75

DAS= days after sowing; 100% recommended = 100 kg N+20 kg P_2O_5/ha

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and dry matter yield of 597 and 186 qha^{-1} respectively. But HCN content decreased with advancement of growth stage of the crop. The application of 125 per cent of recommended nitrogen and irrigation applied 7 days before harvesting also significantly increased fodder yield and improved the quality of sorghum fodder over other levels.

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Sunfish *Ranzania laevis*, a Rare Catch From Harawada (Ankola), Karnataka

Ulhas G. Naik* and Shivakumar B. Haragi

Department of Studies in Marine Biology.
Karnatak University Post Graduate Centre,
Kodibag, Karwar 581 303, Karnataka, India
**E-mail: ugnaik66@yahoo.co.in*

Uttara Kannada coast (13° 58' 45.18"-14° 51'N and 74° 07'-74° 31' 20.24" E), Karnataka state is known for its fin fish resources from time immemorial and has vast coastal stretch of about 143 km comprising five maritime taluka viz., Karwar, Ankola, Kumta, Honnavar and Bhatkal which are blessed with major riverine systems each and contribute much in escalating the productivity of the inshore area. This productivity in turn invites many more commercial pelagic as well as benthic rare fishes to this coast. Recently, one such rare bony fish was caught at Harawada (Ankola taluka) along with Pomfret fishes in the gill net operated by fisherman. The fish commonly called as 'sunfish' *Ranzania laevis* (Pennant 1776). In recent past (more than 30 years) this fish was neither recorded nor sighted at wild by the fishermen and is first time being reported from this coast.

Fish body depth to body length is two times or almost, lips funnel-like forming a vertical slit when closed. Body with scales arranged closely and is hexagonal shape. An elongated pectoral fin fitting in shallow concavity. Its size ranges from smaller to 75 cm in length. Slender fish belongs to the family-Molidae. Totally three genera viz., *Ranzania*, *Masturus* and *Mola* are found in the world and it is the only member of *Ranzania* inhabiting in the tropical and temperate seas. They are bentho-pelagic in nature and found in 1 to 140m depth. Maximum size (total length) of this fish reported is 100.0cm. The caudal (tail) fin is greatly reduced in to clavus.

On 11th November 2011, same species (*Ranzania laevis*) was landed at Chinnapalam fish landing centre at Pamban, south-east coast of India. Total length of fish was 550mm and was incidental catch in kalamkatti valai (similar to gill net) and was rare occurrence in that area. It is coloured with dark grey above and brownish green on sides with dark stripes. Its IUCN Red list Status is "Not Evaluated' (Vinod and Ramamurthy, 2011).

Ranzania laevis species was caught at Harawada (14° 43'27.99" N and 74° 14' 19.54" E), Karnataka (West coast of India) on March 30th 2013. Total length of this fish was 550mm weighed about 4.36kg and was happened to be incidental catch in the gill net operated in the inshore waters of Harawada, the fishing hamlet of Ankola taluka (district Uttara Kannada, Karnataka State). Based on the observed meristic characters and available literatures, it was third report in all over India and first occurrence in the coastal waters of Harawada, Uttara Kannada district. After interacting with local fisherman it was confirmed that the fish was caught at a depth of 8-10m in the drift gill net around 10 km away from the coast. The morphometric measurements were taken to the nearest millimeter and its detailed characters are given in the Table 1.

Fish belongs to Class-Actinopterygii, Order: Tetraodontiformes and Family: Molidae which includes the Molas or Ocean Sunfishes. It is marine, inhabiting in pelagic realm of Ocean up to a depth of 1 to 140m. An elongated body with thick and leathery skin with small denticles; mouth as a vertical slit. No dorsal spines, totally 18 dorsal rays; no anal spine but totally 18 anal soft rays. The caudal fin is present in post larvae but resorbed during metamorphosis and replaced by a clavus.

It is cosmopolitan in distribution. It inhabits in the subtropical region between 71° N and 55°S; 180°W-180°E respectively. Subtropical; 71°N - 55°S, 180°W - 180°E respectively. Indian Ocean: Madagascar (Fricke, 1999), Mauritius (Baissac, 1990), Iran (Koochaknejad, 2011), Oceanic (Eschmeyer *et al.*, 1983), epipelagic (Babiker,1979), and generally solitary (Scott, 1995), feeds on planktonic crustaceans (Heemstra, 1986).

The fish was fresh and alive when it was caught in the net, and there was no ready buyers and was brought to the Institute where its morphometric measurements were made. Later, it was preserved and kept in the Museum of Department of Marine Biology, Karnatak University, Karwar, Karnataka.

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Table 1. Morphological characters of the Sunfish, *Ranzania laevis* from Uttara Kannada coast

Sl.No.	Characters	Dimensions (in mm)
1.	Total length	545
2.	Gross weight	4.36 kg
3.	Head length	196
4.	Eye diameter	34
5.	Post orbital length	105
6.	Pre orbital length	82
7.	Height of the body (linear)	247
8	Pre dorsal length	488
9.	Girth of the body	565
10.	Pre pectoral length	208
11.	Pre anal length	352
12.	Height of Dorsal fin	175
13.	Height of Anal fin	145
14.	Length of caudal (clavus) fin	192
15.	Pectoral fin Length	133
16.	Pectoral fin breadth	28
17.	Dorsal fin base breadth	55
18.	Anal fin base breadth	55
19.	Caudal fin base breadth	230
20.	Distance between base of dorsal and anal fin	235
21.	Distance between base of pectoral and caudal fin	335
22.	Gill aperture	17
23.	Anal aperture	41
24.	Length of mouth	19
26.	Breadth of mouth	23
27.	Fin formula	D18 A18 C19 P14 No lateral line

Table 2. Earlier records of sun fish (*Ranzania laevis*) from Indian coasts

Year of Records	Species	Region	Total length (mm)	References	Remarks
2011	*Ranzania laevis*	Chinnapalam fish landing centre, at Pamban, east coast of India	550	Vinod and Ramamurthy, 2011	First record of Sunfish from East coast of India
2013	*Ranzania laevis*	Harawada, Ankola, Karnataka, West Coast of India	545	Present study	First record of Sunfish from West coast of India

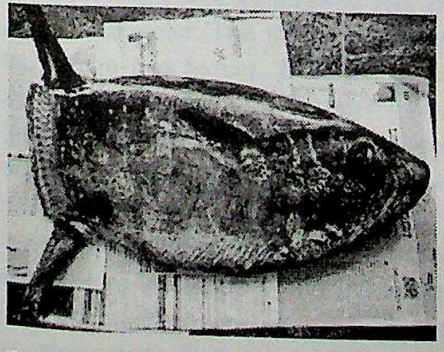


Plate 1. Sunfish *Ranzania laevis* (Pennanta, 1776) caught at Harawada, Karnataka, India

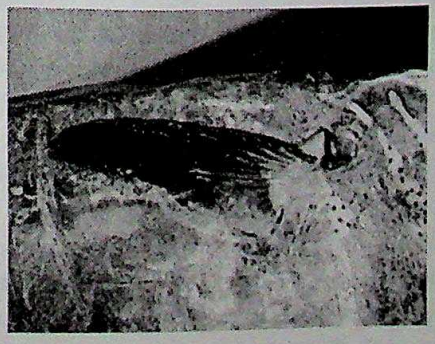


Plate 2. *Ranzania laevis* Pectoral fin fitting into the concavity with small gill opening (pore like)

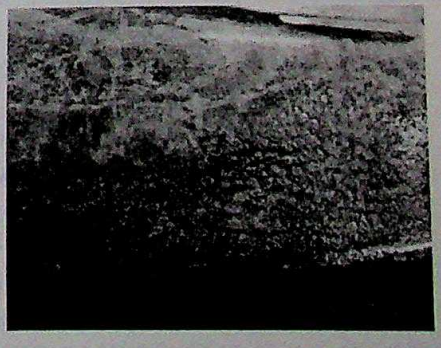


Plate 3. Hexagonal shaped scales on body of Sunfish (*Ranzania laevis*)

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Influence of Agar Concentration on Somatic Embryogenesis and Plant Regeneration in *Indica* Rice

Ruma Devi and Ajinder Kaur

School of Agricultural Biotechnology
Punjab Agricultural University, Ludhiana, 141 004

To expedite genetic improvement in rice, genetic engineering can be a powerful tool and novel compliment to the traditional methods of plant improvement. Further, an efficient tissue culture line with high frequency of plant regeneration is a prerequisite for the development of transgenic plants. There are many reports on the plant regeneration from callus in rice but the number of plants regenerated in all the cases is rather small (Kyozuka *et al.*, 1988). Induction of somatic embryos is an important route for the regeneration of plants on a large scale from cell cultures. The frequency of *in vitro* plant regeneration in rice is reported to be affected by many factors e.g. concentration of gelling agents, osmoticum, antibiotics, genotypes, growth regulators and dehydration of callus (Tsukahara and Hirosawa, 1992). Agar is used as a gelling agent in the plant tissue culture studies. But when used in high concentration, it creates dehydrating conditions and stress on the plant cells that result in a remarkable increase in the production of somatic embryos (Kaur and Gosal, 2009). Therefore, the present experiment was designed to determine the effect of higher concentration of agar on somatic embryogenesis and subsequent plant regeneration from callus cultures in a commercial rice variety of Punjab.

Mature seeds of the variety PR 116 were dehusked and surface sterilized with 0.1 percent mercuric chloride for 10 minutes followed by three to four rinses in the sterile autoclaved water. The sterile seeds were inoculated on Murashige and Skoog, 1962 media supplemented with sucrose (30.0 g l^{-1}), 2,4-D (2.5 mg l^{-1}), kin (0.5 mg l^{-1}), proline (560 mg l^{-1}), agar (0.8 %) i.e. CIM. The pH of media was adjusted to 5.8 by adding 1N NaOH/1N HCl drop-wise. The media was autoclaved at 1.05 kg cm^{-1} square pressure and 121°C temperature for 22 minutes. The inoculated seeds were incubated at 25±1°C in dark for 10-12 days. The scuteller calli were excised and placed on CIM supplemented with 0, 0.4, 0.8, 1.2 and 1.6 percent agar for different duration of time, i.e. 5, 8, 11, 14 and 17 days. The observations were recorded on percent callus induction, somatic embryogenesis. The experiment was replicated four times. The obtained embryos were transferred to the regeneration medium (RM), i.e. MS media supplemented with sucrose (30.0 g l^{-1}), BAP (2.0 mg l^{-1}), kin (0.5 mg l^{-1}), NAA (0.5 mg l^{-1}) and agar (0.8 %). The data were recorded on percent plant regeneration. The shoots were rooted on the half strength MS medium. The plantlets were washed in the running tap and dipped in 0.1 percent solution of bavistin. The plantlets were hardened by placing them in the test tubes containing simple tap water under a higher light intensity (5000 lux) and incubated at 25 ±1°C for a period of five days. The plants were ultimately transferred to the pots. The data was analyzed in factorial CRD (Singh and Cheema (1985).

The analyses of variance for the experimental design revealed that percent somatic embryogenesis varied significantly with the concentration of agar and different durations of subculture period. But, the interaction effects were non- significant between the concentration of agar and durations of subculture period (AxB). The frequency of callus induction was recorded to be 72.53 percent on the CIM followed by only 24.06 to 26.53 percent of shoot regeneration on RM. This implied that the frequency of somatic embryogenesis was very low in the callus cultures on CIM. Partial desiccation of callus has been reported to increase the somatic embryogenesis in rice (Tsukahara and Hirosawa, 1992; Rance *et al.*,1994). Among the different concentrations of agar maximum somatic embryogenesis (77.14 percent) was recorded when the concentration of agar was doubled from the control, i.e. 16 gl^{-1} after subculturing for 11 days. The percent somatic embryogenesis decreased with either increase or decrease from this optimum level of agar. At lower concentrations of agar, the frequency of somatic embryogenesis was little ranging from 28.65 to 54.23 percent, whereas, at higher agar concentrations the calli showed very less percent somatic embryogenesis ranging from 20.21 to 44.15 percent. Further at higher concentrations of agar, the calli turned black in colour and showed a very high mortality rate. Similarly, when the calli were subcultured for lesser duration of time from the optimum level, percent

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Table 1. Effect of concentration of agar and duration of subculture period on percent somatic embryogenesis in rice callus cultures

	Somatic Embryogenesis (%)				
	Days to subculture				
Agar (%)	5	8	11	14	17
0.8	30.46	32.14	34.02	31.49	28.65
0.8 + 0.4	48.12	50.55	54.23	50.83	48.88
0.8 + 0.8	70.94	74.42	77.45	73.28	71.69
0.8 + 1.2	38.65	41.90	44.15	42.57	39.14
0.8 + 1.6	21.83	23.12	26.00	22.99	20.21

CD at 5 % level of significance	
Agar concentration (A)	2.15
Days to subculture (B)	2.15
AxB	NS

embryogenesis decreased significantly, whereas, when cultured for a higher duration of time (14 and 17 days), again the calli turned black in color and showed high mortality rate. Also there was a significant decrease in percent somatic embryogenesis.

The embryogenic secondary calli obtained from different treatments were subcultured on the RM, on which maximum regeneration (83.57 percent) was exhibited by the calli transferred from CIM supplemented with 1.6 percent of agar concentration. Jain *et al.,* (1996) reported that when the agarose concentration in the regeneration medium was increased from 0.5 to 1.0 percent (w/v), the frequency of shoot formation from Pusa Basmati 1 cell suspension-derived calli increased by over eightfold, i.e. upto 86 percent. They also reported that partial desiccation of rice calli resulted upto threefold increase in the shoot regeneration frequency. Saharan *et al.,* (2004) reported that maximum shoot regeneration frequency (63%) was observed in partially desiccated calli for 48 h in *indica* rice. In conclusion, the studies indicate that the dehydration of callus created by adding a higher concentration of agar significantly improved the plant regeneration in rice by improving somatic embryogenesis. Thus, this simple treatment can be well exploited to overcome the problem of low frequency of plant regeneration in rice.

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Effect of Biovita-A Seaweed Extract from *Ascophyllum nodosum* on Yield, Yield Attributes and Nutrient uptake of Wheat (*Triticum aestivum* L.)

Om Prakash, R.N. Meena*, Lalji Yadav and A. Sen

Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005 (U.P.), India
**E-mail:ramnarayanbhu@gmail.com*

In India, a large variation in production of wheat is observed which is mainly due to the inadequate use of plant protection measure, under utilization of the applied nutrients and lack of irrigation facility. This poor nutrient use efficiency is because of inadequate production of natural hormones and enzymes in the plant required for mobilization and conversion of nutrients into basic tissues for optimum plant growth. Biovita specially balanced combination of over 60 naturally occurring major and minor nutrients and plant growth development substances like amino acid, vitamins and hormones (gibberellins, auxins, betains, etc.) in organic form. A seaweed extract derived from seaweed (*Ascophyllum nodosum*) algae, which contains 2% abscissic acid, 3% adenine and 5% indole acetic acid (Kingman and Moore, 1982). It breaks down the complex molecules to simple one which can be utilized by cells (Leopold and Kriedmann, 1988). In addition to these advantages, biovita helps in increasing the activity of microbes in the soil when applied in granular form thereby increasing the nutrients availability. Its use leads to better root growth and greater resistance to environmental and moisture stress condition. Biovita liquid, when used as seed coating has been found to increase and accelerate germination and nutritive value of produce. One of the important features of biovita is that it can be applied at all the stages of plant growth from seeding to fruiting and is a non-toxic natural product. Therefore, the present investigation was conducted to find out the effect of biovita-A seaweed extract from *Ascophyllum nodosum* on yield and nutrient uptake by grain and straw of wheat under zero tillage system and to explore the possibility of improving the productivity and availability on nutrient.

A field experiment was conducted at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University Varanasi, during *rabi* season of the year 2007-08. The eastern indo-gangetic soil of the site was sandy clay loam in texture having pH 7.4 and moderately fertile, organic carbon 0.32% and available N, P_2O_5, K_2O was 195, 16.20 and 216 kg ha^{-1}, respectively. It was a factorial experiment laid out in randomized complete block design (RBD) with 20 treatment combinations allocation in each replication and was replicated thrice. The experiment comprised four levels of biovita granules *viz* – 0 (control), 10, 20 and 30 kg ha^{-1} applied at basal stage and five levels of biovita liquid *viz* – 0 cc ha^{-1} (control), 500 cc ha^{-1} (25 DAS), 500 + 500 cc ha^{-1} (25 and 50 DAS), 500 + 625 cc ha^{-1} (25 and 50 DAS) and 500 + 625 + 750 cc ha^{-1} (25, 50 and 75 DAS). A uniform fertilizer dose of 120 kg N, 60 kg P_2O_5 and 60 kg K_2O was applied in the form of urea, single super phosphate and muriate of potash in all the plots. One-third nitrogen and full dose of phosphorus and potassium was applied as basal and remaining two-third dose of N was applied in two equal splits at crown root and panicle initial stages. The experimental field remained undisturbed with standing rice residue of preceding crop and wheat sown directly in the field by zero- till drill.

Number of spike (m^{-2}), spike length (cm), spike weight (g $spike^{-1}$), grains $spike^{-1}$, test weight (g), grain yield (q ha^{-1}) and straw yield (q ha^{-1}) were observed maximum in application of 10 kg ha^{-1} granules biovita along with recommended dose of NPK were significantly higher over the control and followed by other treatments. Application of 500 + 500 cc ha^{-1} (25 and 50 DAS) liquid biovita along with recommended dose of NPK were recorded the significantly maximum yield and yield contributing characters followed by other treatments. Further increase in dose of liquid biovita failed to show statistical superiority in this respect. This might be due to the presence of enzyme and cytokinin in biovita might have accelerated the carbohydrate synthesis by increasing the dark reaction of photosynthesis which inturn most probably led to reproductive organs (Kumar *et al.*, 2005). Results of the present investigation suggested that wheat gave significantly higher yield and yield contributing characters at 10 kg ha^{-1} granules and 500 + 500 cc ha^{-1} (25 and 50 DAS) liquid biovita.

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Table 1. Effect of biovita on yield attributes and yield of wheat

Treatment	No. spike (m^{-2})	Spike length (cm)	Spike wt. (g $spike^{-1}$)	Grains $spike^{-1}$	Test wt. (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
Granules biovita							
0 kg ha^{-1}	372.00	14.28	2.32	47.53	35.33	34.85	52.44
10 kg ha^{-1}	408.00	15.11	2.60	49.39	37.76	38.76	57.71
20 kg ha^{-1}	394.67	14.56	2.45	48.00	36.57	37.25	54.45
30 kg ha^{-1}	396.00	14.72	2.35	48.53	36.58	36.86	53.09
CD(P=0.05)	7.01	0.12	0.04	0.98	0.16	0.97	1.21
Liquid biovita							
0 cc ha^{-1}	373.34	14.32	2.32	47.41	35.48	35.33	51.13
500 cc ha^{-1} (25 DAS)	388.33	14.52	2.35	47.67	36.02	36.65	53.60
500 + 500 cc ha^{-1} (25 and 50 DAS)	420.00	14.92	2.53	49.33	37.70	38.50	56.96
500 + 625 cc ha^{-1} (25 and 50 DAS)	395.00	14.86	2.44	48.33	36.47	36.93	54.25
500 + 625 + 750 cc ha^{-1} (25, 50 and 75 DAS)	386.67	14.64	2.50	48.33	36.64	37.25	56.17
CD(P=0.05)	7.84	0.13	0.04	1.10	0.18	1.09	1.35

Table 2. Effect of biovita on nutrient content (%) and nutrient removal by grain and straw (kg ha^{-1})

Treatments	Nutrient content (%)						Nutrient removal (kg ha^{-1})					
	Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Granules biovita												
0 kg ha^{-1}	1.95	0.39	0.234	0.075	0.259	0.96	69.03	19.94	7.45	3.56	8.81	48.59
10 kg ha^{-1}	1.88	0.37	0.211	0.070	0.232	0.85	71.89	21.63	7.63	3.74	9.12	50.10
20 kg ha^{-1}	1.89	0.37	0.208	0.064	0.243	0.89	71.63	20.21	7.74	3.80	8.98	48.72
30 kg ha^{-1}	1.91	0.38	0.210	0.067	0.249	0.91	70.80	20.10	7.50	3.68	9.05	49.10
CD(P=0.05)	0.014	NS	0.008	0.002	0.012	0.006	NS	NS	NS	NS	NS	NS
Liquid biovita												
0 cc ha^{-1}	1.97	0.39	0.269	0.078	0.263	0.99	69.88	19.83	7.25	3.60	8.82	48.44
500 cc ha^{-1} (25 DAS)	1.93	0.38	0.212	0.070	0.253	0.92	70.66	20.09	7.49	3.60	8.88	48.91
500 + 500 cc ha^{-1} (25 and 50 DAS)	1.87	0.36	0.189	0.063	0.224	0.82	72.51	21.13	7.75	3.78	9.17	50.27
500 + 625 cc ha^{-1} (25 and 50 DAS)	1.89	0.37	0.207	0.067	0.244	0.89	70.56	20.32	7.65	3.63	9.02	48.51
500 + 625 + 750 cc ha^{-1} (25, 50 and 75 DAS)	1.88	0.37	0.201	0.066	0.243	0.89	72.02	20.97	7.73	3.73	9.06	49.50
CD(P=0.05)	0.016	NS	0.010	0.002	NS	0.008	NS	NS	NS	NS	NS	NS

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Nitrogen content in grain was significantly influenced by both the experimental variables. Persual of the data clearly indicated that all granule and liquid reduced the nitrogen content of grain in comparison to control. Highest nitrogen content in grain (1.97% in liquid and 1.95% in granule) was observed where no (control) biovita was applied and it was found significantly superior to all liquid and granule levels. Although same trend was found in case of straw also, both the variables failed to bring about any significant change in nitrogen content in straw. Control plot registered maximum phosphorus and potassium content both in grain and straw and it remained significantly superior to all other levels. Due to granule and liquid application no significant differences in nitrogen, phosphorus and potassium removal were observed in grain and straw. However, application of 10 kg ha^{-1} granule at basal and 500 cc ha^{-1} at 25 DAS + 50 DAS liquid biovita recorded maximum NPK removal both in grain and straw. This might be due to application of biozyme, which maintain the balance of NPK, increases the availability of micronutrients such as Zn, Mg and Cu in soil and gibberellins and auxin increased the nitrogen and all phytohormones increased the phosphorus content in grain. This finding was supported by Mandal *et al.* (2006) and Wiezbowska *et al.* (2006).

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It was concluded that the yield, yield contributing characters and NPK removal were observed maximum in application of 10 kg ha^{-1} granules biovita at basal stage and 500 + 500 cc ha^{-1} (25 and 50 DAS) liquid biovita along with recommended dose of NPK at basal. The NPK contents were maximum in control plot.

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Diversity and Impact of Invasive Plant Species on Mubarak Mandi Complex in Jammu Region

Renu Sharma*

Entomology Lab (Weed Biocontrol Section)
Deptt. of Zoology, University of Jammu Jammu-180006, India.
**E-mail: ddrenusharmaj@gmail.com*

Jammu region of J & K State is endowed with many beautiful architectonical constructions of historical importance which are either state or centrally protected and Mubarak Mandi Complex in Jammu District of Jammu and Kashmir state is one of them. This complex is also known as 'Durbar Garh" is located on a hillock overlooking the river Tawi in the heart of old Jammu City. The importance of Mubarak Mandi lies in the fact that it was the hub of political and social activities besides being a historical monument and a place of residence of royalty. Presently this complex is housing seventy six government offices and courts. The complex has a long history as old as 150 years back. It was a royal residence of Dogra rulers. The complex consists of a group of buildings around the courtyard.

Due to lack of proper maintenance, this monument of great historical importance is now under the process of deterioration. A major contributor to this process is abundant plant growth. The complex has been abundantly colonized by different plant communities viz. herbs, shrubs, climbers, trees etc.

Present work, a part of wider research project on archeological flora of Jammu region, present a floristic inventory of Mubarak Mandi Complex recorded from different sites (floor, roof, walls and stairs) in different seasons viz. premonsoon, monsoon, postmonsoon. In addition relative abundance of each plant family and Danger Index of each plant species has also been estimated.

A comprehensive survey was conducted by the author during premonsoons, monsoon and postmonsoon seasons for the collection of different plant species growing on this heritage monument. All the available plant species were recorded and collected. Observations were made regarding their occurrence, distribution and modes of colonization. Field observations regarding individual plant species was recorded in a field note book and photography was done with Minolta SLR Camera using Kodak Gold 100 ASA Coloured film. As per availability 3-4 specimens of each plant species were collected from a particular site at one time under one collection number for further reference. Special care was taken to digout the herbaceous plants particularly annuals with intact roots. In case of shrubs and trees representative twigs about 25 cm long with leaves, flowers and fruits etc. were collected in the airtight polythene bags.

The plant material collected during each field visit was carried to the laboratory and was properly preserved and herbarium sheets were made using conventional methods of processing and drying. The preserved plant specimens were identified through the courtesy of Indian Institute of Integrative Medicine (IIIM) Jammu. The identified voucher specimens were mounted in the herbarium file of the size 11.5 x 16.5 inches and each plant species was provided with botanical name, author citation and brief morphological description.

Danger Index or Impact Index of each plant species was evaluated by taking into account three important parameters pertinent to the following aspects as suggested by Signorini (1996).: (a) Life form, (b) Invasiveness and vigour and (c) Features of radical apparatus.

The Danger Index tells us how much a plant species is potentially dangerous for monument. It has proved to be a useful tool in setting up a programme of vegetation control for medieval walls of Termoli (Italy). Danger Index (DI) shows the role of each plant species in deterioration of monuments as follows.

-DI<3	Not Dangerous Species
-4> DI<6	Not Very Dangerous Species
-DI>7	Very Dangerous Species

Survey yielded a total of thirty eight plant species from twenty one families (Table 1). The vegetation on this group of heritage monuments comprises of grasses, herbs, shrubs, climbers and trees. The most wide spread plant family on this monument is Asteraceae. The plants were found growing on roof tops, walls and floor etc. These plants were found to possess: (a) Sticky and small seeds, (b) Perenating rhizomes and root stocks and (c) High reproductive capacity. Ghosh (1959) too found the same

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characteristic in the wall flora of dilapidated walls of Calcutta and its suburbs, in addition to their high lime requirements.

The roots of some plant species found on this monument penetrated the walls to different depths and may reach the ground after emerging from the walls: e.g. the roots of *Ficus benghalensis*, *F. religiosa* and *F. palmata* are stout well branched and woody, 1.5 – 5m in length. They finally penetrate the ground after coming out of the wall damaging it badly. Roots of *Ficus religiosa* and *Ficus benghalensis* have been found to be very destructive to the walls in wall flora of Gorakhpur (Srivastava *et al.* 1983).The wall flora of various regions of India and world [Singh *et al.* (1979), Srivastava *et al.* (1983), Krigas *et al.* (1999), Grapow & Blasi (2003), Lisci *et al.* (2003), Caneva *et al.* (2003)] shows that the members of family Moraceae have great potential to grow on such specialized microhabitats which provide an extreme environment for the plant life in many respects such as the availability of room for settlement, the hardness and alkalinity of substratum, the inclination, the increased temperature and reduced humidity. The plants like *Calotropis procera*, *Adhatoda vasica*, *Tridax procumbens, Boerhavia diffusa* develop 1-2 cm thick and 21 cm -1.5 m long woody tap roots which penetrate the wall and reach ground through it .In contrast to this the roots of herbaceous species and grasses were profusely branched and remain confined to the wall mortar.

To know the deteriorative effect of a particular plant species on the archeological site., the Impact Index (IP) or Danger Index (DI) given by Signorini (1996) was calculated. Corbetta *et al.* (2002) and Grapow and Blasi (2004) did the same study to estimate the relative deteriorating effect of each plant species growing on the archeological sites of

Table 1. Plant Diversity and Danger Index (DI) of each plant species recorded on Mubarak Mandi Complex.

Name of the plant	CommonName	Family	DI
Acacia modesta Wall.	Phulai	Mimosaceae	8
Achyranthes aspera Linn.	Puth Kanda	Amaranthaceae	5
Adhatoda vasica (L.) Nees	Barenkar	Acanthaceae	8
Adiantum venustum D.Don	Kali Kakoi	Adiantaceae	4
Amaranthus viridis Linn.	Chalari	Amaranthaceae	1
Argemone mexicana Linn.	Kandiara	Papaveraceae	2
Barleria prionitis Linn.	Kali Barenkar	Acanthaceae	5
Bidens chinensis (L.) Willd.	Kumbar	Asteraceae	3
Blumea laciniata (Roxb.) DC.	Shashal Mashal	Asteraceae	1
Boerhavia diffusa auct. plur.	It-sit	Nyctaginaceae	5
Calotropis procera (Willd.) R. Br.	Akk	Asclepiadaceae	5
Carissa opaca Stapf ex Haines	Garna	Apocynaceae	6
Chenopodium murale Linn.	Karun	Chenopodiaceae	1
Datura innoxia Mill.	Datura	Solanaceae	5
Eclipta prostrata Linn.	Bhringaraj	Asteraceae	2
Euphorbia hirta Linn.	Suhi Dudali	Euphorbiaceae	3
Evolvulus alsinoides Linn.	Nili Shankhpushpi	Convolvulaceae	4
Erigeron bonariensis Linn.	Boordar Buhti	Asteraceae	3
Ficus benghalensis Linn.	Bori	Moraceae	9
Ficus palmata Forssk.	Phakari	Moraceae	8
Ficus religiosa Linn.	Bar	Moraceae	10
Flueggea virosa Roxb.	Rathali	Euphorbiaceae	8
Fumaria indica Pugsley	Pit-Papra	Fumariaceae	2
Grewia optiva J.R. Drum.	Dhaman	Tiliaceae	8
Kickxia ramosissima Janchen.	Madhumeh Jari	Scrophulariaceae	4
Lantana camara Linn.	Panjphuli	Verbenaceae	6
Lepidagathis cuspidata Nees	Ount Kanteli	Acanthaceae	6
Lindenbergia macrostachya Benth.	Gajoor	Scrophulariaceae	4
Malvastrum coromandelianum Garcke	Baddi-Barear	Malvaceae	4
Mazus japonicus (Thunb.) Kuntze.	Japanese mazus	Scrophulariaceae	2
Morus alba Linn.	Toot	Moraceae	8
Murraya koenigii (L.) Spreng.	Kari-Patta	Rutaceae	6
Oxalis corniculata Linn.	Khatti-Buhti, Ammi	Oxalidaceae	2
Parthenium hysterophorus Linn.	Congress ghas	Asteraceae	3
Pergularia extensa (Jacq.) N.E.Br.	Utran	Asclepidaceae	6
Sida rhombifolia Linn.	Chitti Badoli	Malvaceae	5
Solanum nigrum Linn.	Kayan-kothi	Solanaceae	3
Tridax procumbens Linn.	Kumra	Asteraceae	4

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Neapolis (Syracuse, Sicily) and Italy respectively. Impact Index reveals that trees are more destructive to the monument followed by shrubs and herbs (Corbetta *et al.*, 2002; Grapow and Blasi, 2004). Of the 38 plant species recorded following plant species are detrimental to the monuments in view of their high Danger Index (DI). Trees like, *Ficus religiosa, F. benghalensis, F. Palmata, Flueggea virosa* and shrubs like *Adhatoda vasica, Lantana camara* and *Murraya koenigii*. Herbs were found to be less dangerous except some viz. *Boerhavia diffusa* and *Achyranthes aspera* which were found to have deep penetrating tap roots than others.

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Seasonal Incidence of *Leucinodes orbonalis* Guen. on Brinjal *Solanum melongena* L.

R.G. Samota*, B.L. Jat and M.R. Bajya*

Department of Entomology, SKNCOA, Jobner-303329
Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan, India.
**Institute of Pesticide Formulation Technology Gurgaon, (Haryana) 122016s*
**E-mail: ramopal.765@gmail.com*

Brinjal, *Solanum melongena* L. belongs to Solanceae, is an important vegetable crop grown through out the world, especially in South Asia and a native of India. It has several vernacular names *viz.*, egg plant, aubergine, baingan badone, kausi, vangi, vazhuthana (Yawalkar, 1985). Brinjal is highly productive and usually finds its place as the poor man's crop. It is rich source of minerals like calcium, magnesium, phosphorus, sodium, potassium, chlorine, iron, vitamins and also has some medicinal importance (Choudhary, 1967). In production and productivity, India stands second in the world after China which is mainly grown in the states like West Bengal, Orissa, Bihar, Gujarat, Maharashtra, Andhra Pradesh, Karnataka etc. with an area of 6.0 lac hectares with an annual production of 103.78 lac tones (Anonymous, 2009) and Rajasthan had 0.052 lac hectare area with an annual production of 0.23 lac tones (Anonymous, 2005). In the Rajasthan state, it is mainly grown in Alwar, Jaipur, Ajmer, Bharatpur, Bundi, Baran and Kota districts. The brinjal crop is attacked by a number of insect-pests right from germination to harvest of the crop *viz.*, shoot and fruit borer, *Leucinodes orbonalis* Guen.; jassid, *Amrasca biguttula biguttula* (Ishida); aphid, *Aphis gossypii* Glover; lace wing bug, *Urentius sentis* Distant; leaf feeding beetle, *Epilachna vigintioctopunctata* Fab. and stem borer, *Euzophera perticella* Ragonot. Among these insects, shoot and fruit borer, *L. orbonalis* is one of the major constraint in achieving potential yield and remain active throughout the year with many overlapping generations. Crop losses have been reported to the tune of 20-89 per cent in various parts of country by this pest (Raju *et al.*, 2007).

To study the seasonal incidence of *L. orbonalis* on brinjal in relation to weather parameters, variety 'Pusa Purple Round' was transplanted on 27th July 2009 at SKNCOA, Jobner in four plots of 3 x 3 m^2 size keeping row to row and plant to plant distance of 60 and 50 cm, respectively. For this purpose the crop was left for natural infestation of *L. orbonalis*. The observations on shoot infestation at weekly interval and fruit infestation at each picking were recorded. The data recorded on shoot and fruit infestation and meteorological parameters were used for statistical analysis (Panse and Sukhatme, 1967). The simple correlation was computed between per cent shoot and fruit infestation and weather parameters, *viz.*; maximum and minimum temperatures, relative humidity and rainfall. The formula of Gupta (1996) was used for calculating correlation.

In the present investigations, the infestation of shoot and fruit borer on shoots of brinjal crop, commenced in the second week of August (1.50%), which gradually increased and reached its peak in the third week of September (28.50%), thereafter it started declining. The present results are in agreement with those of Mall *et al.* (1992) who reported that the infestation of *L. orbonalis* on shoots of brinjal started in the third week of August and reached its peak during September. Similarly, Singh *et al.* (2000) reported that infestation of *L. orbonalis* on brinjal shoot commenced in the end of August and reached its peak in the third week of September. The present findings also get support from the findings of Oommen and Kumar (2004), Singh *et al.* (2006) and Mahesh and Men (2007).

The infestation on fruits started in the first week of October (15.30% on number and 12.30% on weight basis), which gradually increased and reached its peak (62.50 and 60.25%) in the fourth week of October at 33.4°C maximum temperature, 10.6°C minimum temperature with 36 per cent relative humidity. The present findings are in agreement with Oommen and Kumar (2004) who reported maximum infestation on fruits during the third week of October. Likewise, Singh *et al.* (2000) and Singh *et al.* (2006) also reported that the infestation of *L. orbonalis* on brinjal started in first week of October and reached to its peak in second fortnight of October support the present results. The results also corroborate with that of Mahesh and Men (2007) who observed peak larval population of *L. orbonalis* in fruits of brinjal during mid of October with 21.4-33.0°C temperature, 45-86 per cent relative humidity, 2.5 mm rainfall and 7 hour

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Table 1. Seasonal incidence of shoot and fruit borer, *L. orbonalis* on brinjal crop in relation to weather parameters in 2009 (shoot infestation)

SMW*	Date of observations	Shoot infestation (%)**	Temperature (°C)		Relative humidity (%)	Rainfall (mm)
			Maximum	Minimum		
32	12.08.09	1.50	37.1	26.4	52	01.8
33	19.08.09	3.50	33.1	24.8	72	31.0
34	26.08.09	14.75	33.5	23.5	67	03.8
35	02.09.09	15.50	34.7	25.2	61	04.8
36	09.09.09	25.45	35.7	23.2	65	12.4
37	16.09.09	28.50	34.5	21.4	59	06.8
38	23.09.09	18.00	38.6	23.8	41	-
39	30.09.09	24.50	38.5	21.0	42	-
40	07.10.09	20.10	34.1	22.2	64	-
41	14.10.09	16.10	35.1	19.3	46	-

* Standard meteorological week; ** Mean of four plots

of sunshine. The correlation studied revealed that the infestation of *L. orbonalis* on brinjal shoots had significant negative correlation with minimum temperature (r= -0.6536), whereas, non-significant correlation with maximum temperature (r = 0.1608) and relative humidity (-0.1835).

The infestation of *L. orbonalis* on fruits of brinjal both number and weight basis had significant positive correlation with maximum temperature (r = 0.6518 on number and 0.6477 on weight basis) whereas, non-significant correlation with minimum temperature (r = 0.2134 and 0.1967) and relative humidity (r = 0.4740 and –0.4879). The present findings partially in agreement with the findings of Mall *et al.* (1992) who reported that the infestation of the pest on shoots of brinjal did not seem to be influenced by any environmental factors. However, in the present study minimum temperature effect negatively on the infestation of pest and on the fruits maximum temperature and relative humidity effect positively and minimum temperature effect negatively. Kumar *et al.* (1997) reported that incidence of *L. orbonalis* on brinjal significantly affected by temperature and less by other environmental factors, support the present findings. The present findings are also in agreement with the findings of Singh *et al.* (2000) and Oommen and Kumar (2004) who reported that infestation of pest on fruits had positive correlation with maximum temperature and relative humidity and negative with minimum temperature, however, in the present findings minimum temperature and relative humidity had non-significant correlation with pest infestation on fruits of brinjal. Contrary to the present findings (Prasad and Logisawaran,1997) reported that incidence of shoot damage by *L. orbonalis* affected positively by maximum temperature and relative humidity and negatively by minimum temperature. The study is also helpful to minimize the population of regular pests through changing the cropping pattern.

Table 2. Seasonal incidence of shoot and fruit borer, *L. orbonalis* on brinjal crop in relation to weather parameters in 2009 (Fruit infestation)

SMW*	Date of observations	Fruit infestation (%)**		Temperature (°C)		Relative humidity (%)	Rainfall (mm)
		Number basis	Weight basis	Maximum	Minimum		
40	7.10.09	15.30	12.30	34.1	22.2	64	-
41	14.10.09	32.15	30.33	35.1	19.3	46	-
42	21.10.09	52.30	56.60	33.4	17.7	51	-
43	28.10.09	62.50	60.25	33.4	10.6	36	-
44	04.11.09	55.50	53.11	34.4	11.6	43	-
45	11.11.09	40.20	35.65	32.3	13.3	43	-
46	18.11.09	25.00	22.13	25.4	13.9	59	1.2
47	25.11.09	15.50	13.00	27.0	7.0	45	-
48	02.12.09	10.20	9.50	27.4	6.8	47	-
49	09.12.09	5.00	4.45	27.1	7.7	47	-

* Standard meteorological week; ** Mean of four plots

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Table 3. Correlation coefficient between the infestation of *L. orbonalis on brinjal crop* and weather parameters

Particular	Correlation coefficient (r)		
	Shoot infestation (%)	Fruit infestation (%)	
		Number basis	Weight basis
Maximum temperature	0.1608	0.6518*	0.6477*
Minimum temperature	-0.6536*	0.2134	0.1967
Relative humidity	-0.1835	-0.4740	-0.4879

* Significant at 5 per cent level of significance

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Studies on CMCase Production from *Trichoderma reesei* Using Different Media and other Variables under Solid State Fermentation

Seema Ahuja[1]*, Pawanjot Kaur[1], Arshdeep Kaur[2]

**Department of Agriculture, Baba Farid College, Deon, Bathinda-15001 (Punjab) India*
*** Department of Microbial Biotechnology, Dolphin College of Life Sciences, Chuni Kalan: Fatehgarh Sahib-140307 Punjab*
**Email: seemaahuja960@gmail.com*

Among all the biomolecules, cellulose is the dominating waste material from agriculture & man made activities. Agro-food processes generate millions of tons of waste each year (Xiros and Christakopoules, 2009) such as sugarcane bagasse, wheat straw & rice straw. The enzymatic hydrolysis of cellulose materials to produce fermentable sugars has an enormous potential in meeting global bio-energy demand. Hence, rice straw is one of the most abundant ubiquitous wastes by-product worldwide and provides alternative substrate to produce useful chemicals such as biofuel. Cellulase enzymes promote the cellulose degradation to cope with the problems of food and energy shortage expected in near future due to explosive increase in human population. Among the cellulolytic fungi *Trichoderma reesei* has the strongest cellulase degrading activity and its cellulase has been widely investigated. The ability of this microorganism to degrade polysaccharides like cellulose is of considerable interest both in terms of microbial ecology and from the view point of industrial microbiology. Apart from textile industry, cellulases have been used for several years in food processing, waste water treatment & detergent formulation. Considering the importance and application of the cellulases, the present studies were aimed to screen the indigenous fungal isolates for the cellulolytic ability. Furthermore, this study aims to provide better understanding of condition for the production and activity of cellulases by different fungal cultures.

The fungal strain named *Trichoderma reesei* MTCC No. 65 was used in the present studies. Malt Agar (MEA) was used for growth, maintenance & cultivation of the fungal strain. MEA consisted of malt Extract (20 g l^{-1}) and agar (20g l^{-1}). The pH was kept at 6.5. The mineral salt solution used for solid state fermentation consisted of $(NH_4)_2SO_4$ (10 g l^{-1}), KH_2PO_4 (3 g l^{-1}), $MgSO_4.7H_2O$ (0.5 g l^{-1}) & $CaCl_2.H_2O$ (0.5 g l^{-1}). The fungal spore suspension was prepared for inoculation according to the methods of Rhodes *et.al.* (1959). The PDA slants were streaked and incubated at 25°C for 7 days. After incubation, a uniform suspension of spores was prepared in sterile distilled water containing 0.1% Tween-80. Absorbance was adjusted to 0.7 at 600nm using sterile distilled water as blank. Rice husk, wheat bran, rice bran and bagasse were used individually for production of enzyme. Thermo-chemical treatment was given to solublize some of the hemicelluloses and lignin to expose cellulose. Five gram of each substrate, moistened with mineral solution in the ratio 1:2 was taken as the basal medium for solid state fermentation (SSF). The moistened substrate was taken in 250 ml Erlenmeyer flasks, autoclaved (121°C, 15 minutes), cooled and then inoculated with 10% of standard inoculums (A_{700}, 0.7) obtained from PDA slants. Incubation was done for 5 days at 28°C under static conditions. The extracellular enzyme was extracted by adding 50ml of distilled water to the flask of solid-state culture. The flasks were kept on the rotator shaker (28°C, 150rpm) for 1hr. After shaking, the contents of the flasks were filtered through 40 mesh sieves and the solid residue was pressed to release any remaining liquid. The final volume of this released liquid was noted down after centrifuging it at 10,000 rpm for 15 minutes and cell free supernatant was then used for assaying the enzyme as described below:

Carboxy Methyl Cellulose (CMC) in the presence of endo-β-1, 4-glucanase was converted to reducing sugars, which was estimated by DNSA method (Miller, 1959). 0.5 ml of 1% CMC (low viscosity) prepared in 0.1 M phosphate buffer (pH 7.0) was added to 0.5 ml of appropriately diluted enzyme sample. Reaction mixture was incubated at 50°C for 30 minutes. Substrate control (0.5ml of 1% low viscosity CMC in 0.5 ml 0.1 M phosphate buffer), enzyme control (0.5 ml of enzyme supernatant in 0.5 ml of 0.1 M phosphate buffer) were also run along with the reagent blank. After incubation, reducing sugars were estimated. Concentration of glucose liberated in the test sample, substrate control and enzyme control was determined by referring to standard curve prepared with glucose (concentration ranging from 100-1000 mg/ml).

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The substrate which gave maximum enzyme activity was pretreated with 0.5% NaOH for 18 hrs at room temperature. After 18 hrs, the substrate was autoclaved at 121°C with 15lbs pressure for one hr. Effect of pretreatment of the substrate was studied by comparing the enzyme activity of substrate used in two different manners i.e. without pretreatment and pretreatment of substrate. Effect of different incubation temperatures was studied by incubating the inoculated flasks at different temperatures (25, 28, 37, 40 and 45°C) at 150 rpm for 5 days. After incubation, enzyme was extracted and endoglucanase (CMCase) activity was assayed. Effect of different pH was studied by altering the pH of mineral solution used for moistening of solid substrates in the pH range of 4.5-6.5.Effect of moistening the substrate using mineral solution / distilled water was also studied. In one flask, 5g substrate and 10ml of mineral salt solution was added and in second flask 5gm substrate was used with 10ml of distilled water.

Out of the four substrates tried, maximum endoglucanase activity was observed when rice husk was used as the substrate. The CMCae activity was 12.57% higher as compared to enzyme activity when wheat bran was used as substrate. Similarly, the enzyme activity was 20.15% and 25.95% higher as compared to rice bran and bagasse, respectively. Thus, rice husk was observed to be the best substrate for CMCase production. The highest yield of CMCase using rice husk was possible probably due to the presence of various suitable nutrients present in rice husk or due to its most suitable particle size and consistency required for the anchorage, colonization and enzyme secretion by *T. reesei.* Rice husk proving to be the best substrate was used as solid substrate for further CMCase production studies.

In another experiment, the rice husk pretreated with 0.5% NaOH, for delignification, was used for production of enzymes and compared with the non-treated sample of the substrate. The results revealed that the CMCase was higher (88.96 IU/g) when rice husk pretreated with 0.5% NaOH was used and the percentage increase in enzyme activity was 32.19% over the non treated substrate. These results were in agreement with results of Bjerre *et.al.,* (1996) who found that dilute NaOH was an effective pretreatment for lingo-cellulosic materials.In another study, Damisa *et.al.* (2008) studied cellulase production from *Aspergillus niger* (AH3 mutant) and observed an increased cellulase production when the substrate was pretreated with NaOH. It is, therefore, proposed that pretreatment of substrate with NaOH may result in swelling of particles, causing easy removal of lignin and cellulose depolymerization.

Incubation of inoculated flasks at different temperatures (25°C, 28°C, 37°C, 40°C and 45°C) indicated 28°C to be the optimal temperature for production of CMcase by *T. reesei* . The enzyme activity increased from 70.6 IU/g to 84.13 IU/g when the incubation temperature increased from 25°C to 28°C. However, further increase in temperature led to decrease in enzyme activity and the activities at 37°C, 40°C & 45°C were 59.20, 44.27 and 29.69 IU/g, respectively.

Study carried out in the pH range of 4.5-6.5 (4.5, 5.0, 5.5, 6.0, 6.5). *T. reesei* showed maximum endoglucanase activity (94.12 IU/g) at pH-6.0. The enzyme activity increased from 59.25 to 94.12 IU/g when pH increased from 4.5-6.0 and further increase in pH to 6.5 led to decrease in enzyme activity.

Maximum cellulase production from *T. reesei* ZV-02 has already been reported when the initial pH was adjusted between 4.5 and 6.0 and no significant change was observed in enzyme production within this pH profile (Xia and Cen, 1999) and the optimum value for cellulose production was found to be at pH 4.8. But in the present study the optimum pH for cellulase production was 6.0. As the metabolic activities of the microorganisms are very sensitive to changes in pH, so, cellulase production by *T. reesei* was affected by varying pH of the medium. The difference from the results of earlier workers may be due to the strain of the fungus used in the present study.

When mineral solution was used as moistening agent and compared with use of distilled water alone, the enzyme activity was higher with mineral salt (95.23 IU/g) over the use of the distilled water (82.37IU/g).

It can, thus, be concluded that, maximum endo-glucanase (CMCase) activity (59.31 IUs/g) was achieved with rice husk; highest enzyme activity was observed by thy pretreatment of the substrate with 0.5% NaOH (88.96 IU/g); incubation of the inoculated substrate at 28beC for 5 days (84.13 IU/g), pH value of the substrate at 6.0 (94.12 IU/g) and moistening of the substrate with mineral solution (95.23 IU/g).

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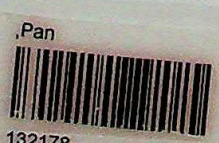
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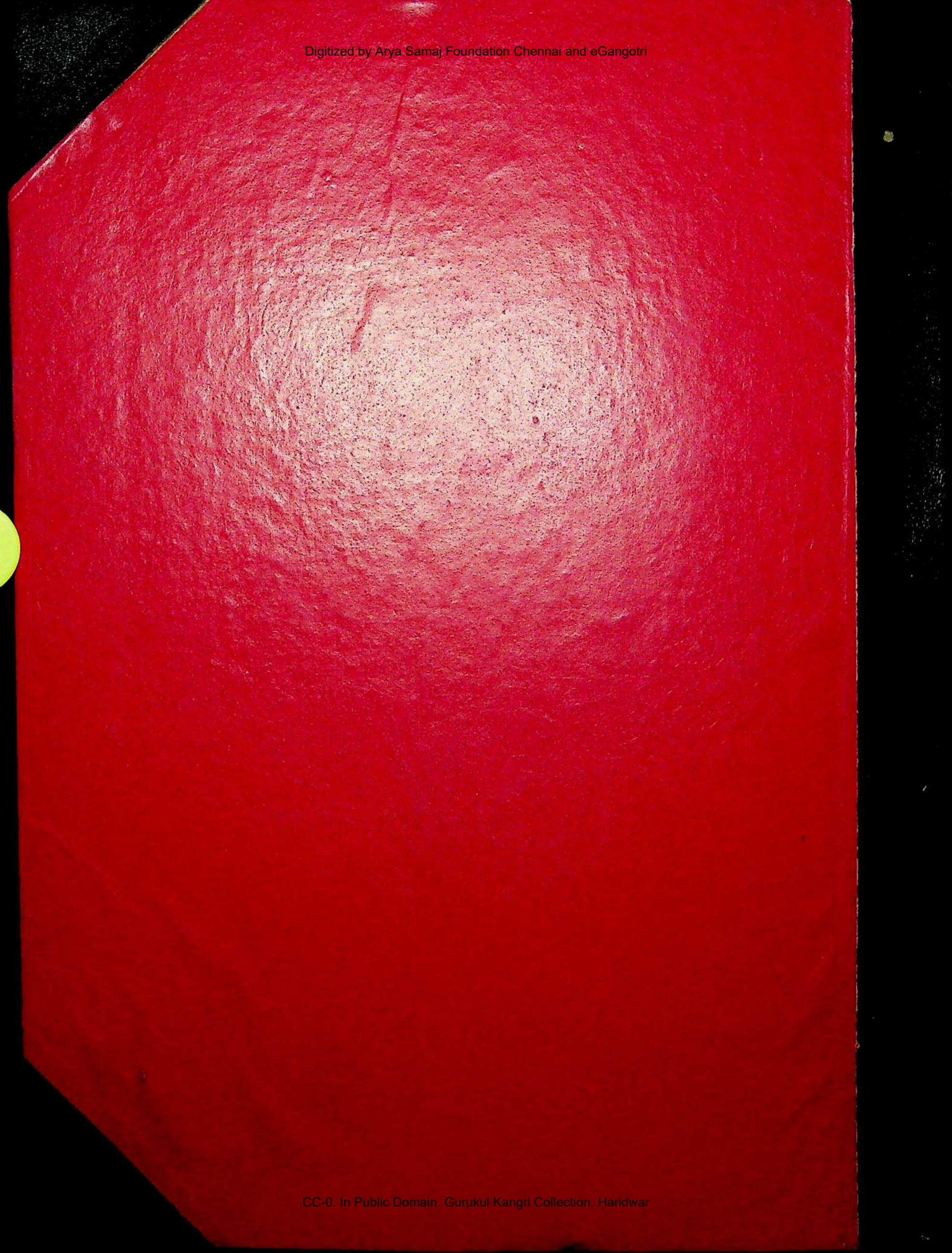
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